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AERONAUTICAL ENGINEERING REVIEW

APRIL 1953

It's a Matter of Record

Bendix Ignition Analyzers Are Performance Proven by Leaders in Aviation, Industry and by the Military Services

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Cover—This shot of the XF2Y-1 Sea-Dart, a jet-powered seaplane built by Consolidated Vultee Aircraft Corporation for the U.S. Navy, was taken immediately after its initial launching preparatory to starting preflight runs. This experimental delta-wing seaplane is equipped with hydroskis, the first such application to a combat-type aircraft in this country. The XF2Y-1 is powered by two Westinghouse turbojet engines. All performance details are classified.

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AERONAUTICAL ENGINEERING REVIEW

Vol. 12 **APRIL, 1953** **No. 4**

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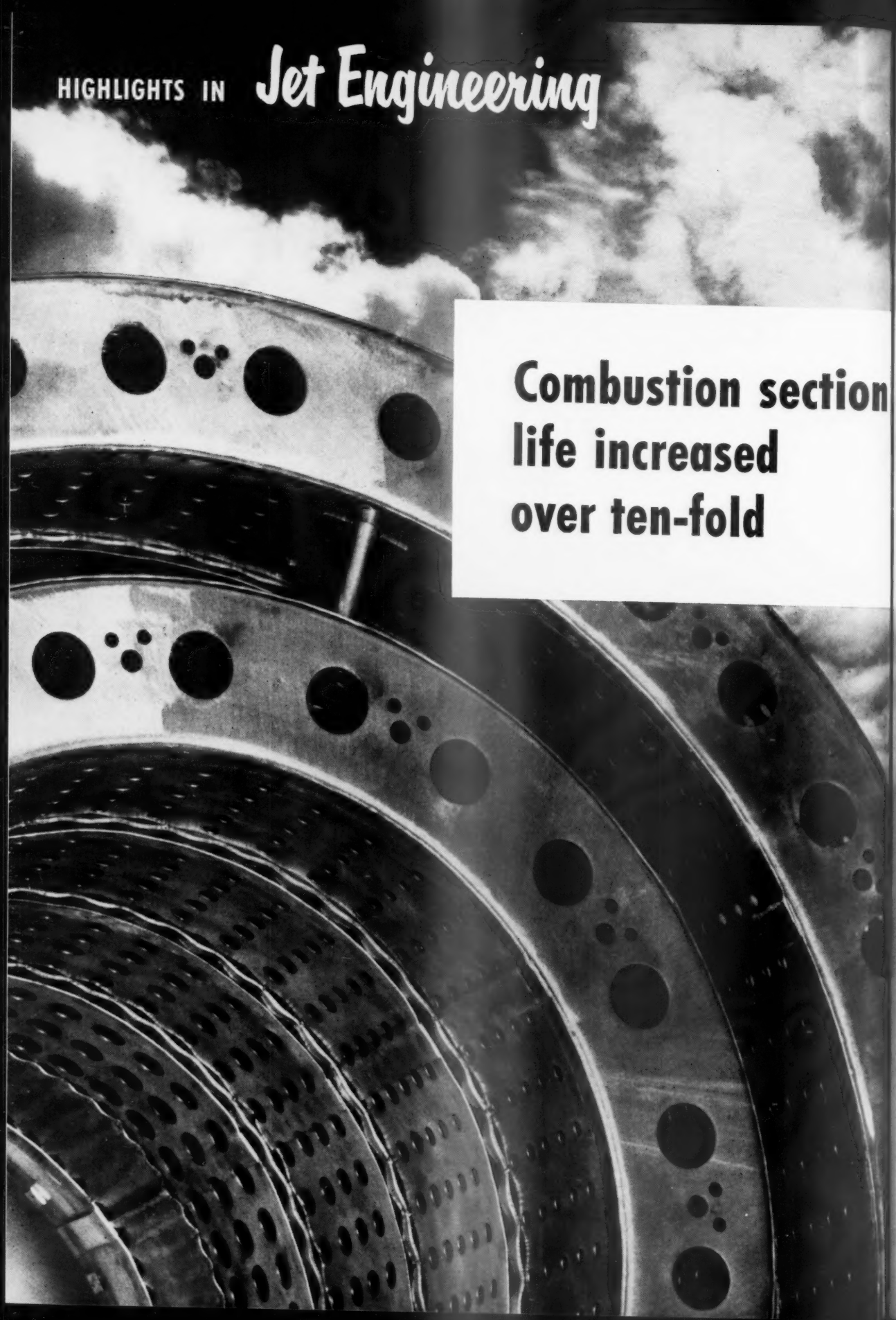
HIGHLIGHTS IN *Jet Engineering*



Combustion section life increased over ten-fold

I.A.S. News Notes

April 1953

APPLICATIONS TO ATTEND INTERNATIONAL CONFERENCE DUE MAY 1

Notices regarding the 4th I.A.S.-R.Ae.S. International Aeronautical Conference, to be held in London, September 7-17, have now been mailed to all Institute members. Those wishing to attend should write to the Institute Secretary, Mr. R. R. Dexter, for formal application blanks immediately. Attention is called to the fact that APPLICATIONS MUST BE FILED AT I.A.S. HEADQUARTERS BY MAY 1.

* * * * *

1953 AERONAUTICAL ENGINEERING CATALOG NOW AVAILABLE

The latest Catalog, just off press, has been greatly expanded and improved over previous editions. Copies are being mailed immediately to all members who have requested them previously. Other members, who have specific need for a products directory of this type, may obtain one free copy by sending in a request. A limited number are available to nonmembers at a price of $7.50 per copy.

* * * * *

U. OF MICHIGAN SHORT-COURSE IN GAS TURBINES OFFERED

An intensive course in gas turbines will be presented at the University of Michigan from June 29 to July 10. Requests for information should be directed to: Frank L. Schwartz, Professor of Mechanical Engineering, 231 West Engineering Building, University of Michigan, Ann Arbor, Michigan.

* * * * *

FIRST IOWA THERMODYNAMICS SYMPOSIUM

A two-day symposium on Thermodynamics is being held on April 27-28 at the State University of Iowa, Iowa City. Further information may be obtained by writing there to Dean Francis M. Dawson, College of Engineering.

* * * * *

NECROLOGY

Mrs. Minta Martin, mother of I.A.S. Honorary Fellow, Glenn L. Martin, and one of the country's oldest and most ardent woman aviation enthusiasts and supporters, passed away at the Martin home in Baltimore on March 14.

* * * * *

NATIONAL MEETINGS CALANDAR

May	20-22	I.A.S., A.I.E.E., and I.S.A. Joint International Telemetering Conference, Edgewater Beach Hotel, Chicago, Illinois
July	15-16	Annual Summer Meeting and Honors Dinner, Los Angeles, California
Sept.	7-17 c	Fourth International Aeronautical Conference, London, England

* * * * *

I.A.S. News Notes (con't.)

CALANDAR OF SECTION MEETINGS

April 1---Philadelphia Section: Engineers' Club of Philadelphia, Dinner, 7:00 p.m.; Meeting, 8:00 p.m. Speaker and subject not known at press time.

April 1---Wichita Section: Location not known at press time. "Helicopters in Korea" by Tom Harriman, Assistant Chief Engineer, Bell Aircraft Co.

April 2---San Diego Section: I.A.S. Building, Dinner, 7:00 p.m. "Aircraft Anti-Icing" by Vic Hudson, of Convair, and Carl Christianson, of United Air Lines.

April 3---Los Angeles Section: I.A.S. Building. Symposium on "Frontiers of Man-Controlled Flight." (Cosponsored by Institute of Transportation and Traffic Engineering of U.C.L.A. and presented by the Aeromedical Engineering Association.)

April 7---Washington Section: Natural History Museum, Smithsonian Institution, Meeting, 8:00 p.m. "Aviation Safety Research Trends and Technology" by William Littlewood, American Airlines; Dr. T. L. K. Smull, N.A.C.A. Frank Brady, A.T.A.; and Jerome Lederer, Flight Safety Foundation.

April 9---Los Angeles Section: I.A.S. Building, Specialist Meeting, 8:00 p.m. "Ram-Air Turbine Driven Auxiliary Power Units for Missiles" by Edward I. Brown, Marquardt Aircraft Co.

April 13---Boston Section: Raytheon Mfg. Co., Newton, Mass., Meeting, 8:00 p.m. "Future Trends in Aviation" by Dr. C. C. Furnas, Director, Cornell Aeronautical Laboratory.

April 16---Los Angeles Section: I.A.S. Building, Social Hour, 5:30 p.m.; Dinner 6:30 p.m.; Meeting, 8:00 p.m. Speaker and subject not known at press time.

April 21---Cleveland-Akron Section: To be held in Cleveland, but exact location not known at press time, Meeting, 6:30 p.m. "Engineering Aspects of Supersonic Flight" by C. L. Johnson, Lockheed Aircraft Corp.

April 22---St. Louis Section: Forest Park Hotel, Dinner Meeting, 6:30 p.m. "The Airport Problem" by Charles F. Horne, former C.A.A. Administrator. (Joint N.A.A.-I.A.S. Meeting.)

April 22---Toronto Section: Room 254, Mechanical Engineering Building, University of Toronto, Meeting, 8:15 p.m. "Engineering Aspects of Sailplane Design and Flight" by Paul Schweizer. (Date for this meeting is tentative.)

April 23---Los Angeles Section: I.A.S. Building, Specialist Meeting, 8:00 p.m. "Some Aerodynamic Effects of Streamwise Gaps in Low-Aspect-Ratio Lifting Surfaces at Supersonic Speeds" by Z. O. Bleviss and R. A. Struble, Douglas Aircraft Co.

April 23---San Diego Section: I.A.S. Building, Specialist Meeting, 7:30 p.m. "Instrumentation."

April 28---Hagerstown Section: Packet Room, Terrace Restaurant, Social Hour, 7:30 p.m.; Meeting, 8:00 p.m. "Vertically Rising Airplanes" by Charles H. Zimmerman, N.A.C.A.

May 27---St. Louis Section: Engineers' Club, Dinner Meeting, hour not known at press time. (Joint S.A.E.-I.A.S. Meeting to which students of local branches are being invited.)

* * * * *

I. A. S. News

A Record of People and Events of Interest to Institute Members

Comments on the Twenty-First Annual Meeting

Registration for Technical Sessions Approximates Last Year's All-Time High; Capacity Crowd Attends Honors Night Dinner; Jeffries, Losey, Reed, and Sperry Awards Presented

THE TWENTY-FIRST ANNUAL MEETING of the Institute of the Aeronautical Sciences, which marked the completion of two decades of service to the aeronautical profession, drew one of the largest groups of aeronautical engineers and scientists yet to attend an I.A.S. annual meeting. The registration for the entire 4 days of technical sessions was over 1,300 and included representatives from all parts of the world and from every known field of the aeronautical sciences.

▸ **Honors Night Dinner**—Some 1,400 persons gathered in the Grand Ballroom of the New York's Hotel Astor on the evening of January 26 on the occasion of the I.A.S. Honors Night Dinner. This exceeded by 200 persons last year's attendance at the Dinner.

The presentations of the I.A.S. Honorary Fellowships and Fellowships and of the Jeffries, Losey, Reed, and Sperry awards were a high point of the evening's program. The outgoing I.A.S. President, Wellwood E. Beall, Senior Vice-President of Boeing Airplane Company, made the awards to their respective recipients. Further details concerning the presentations of the fellowships and awards can be found e'sewhere in this issue. This includes photographs of the two Honorary Fellows, eight Fellows, and four award winners, as well as pertinent information on the awards themselves.

▸ **Dinner Speaker**—The Guest of Honor and Principal Speaker of the evening was General Hoyt S. Vandenberg, U.S.A.F., Chief of Staff of the United States Air Force. The text of his address on "Air Power and New Weapons" will be found on page 18 of this issue.

▸ **Technical Sessions**—There were 15 technical sessions given this year. Each one of them was marked by good attendance and excellent papers and discussions.

On January 26, the first day of the 4-day meeting, sessions were held on the subjects of Flight Propulsion, Structures, Aircraft Design, and Rocket Propulsion. The last-named session was held in cooperation with the American Rocket Society.

The entire day of Tuesday, January 27, was taken up with three sessions on Aerodynamics. The following day, January 28, saw the presentation of three sessions (two of them in the form of a symposium) on Electronics in Aviation and one on Meteorology. The electronics program was arranged in cooperation with the Institute of Radio Engineers, Institute of Navigation, and Radio Technical Commission for Aeronautics, while the meteorology session was held jointly with the American Meteorological Society.

On the fourth and final day of the Twenty-First Annual Meeting, sessions on Aviation Medicine, Motorless Flight, (held in cooperation with the Soaring Society of America) Air Transport—Safety, and Rotating Wing Aircraft were held. The session on Air Transport—Safety was given jointly with The Daniel and Florence Guggenheim Aviation Safety Center at Cornell University; the Rotating Wing Aircraft session was presented jointly with the American Helicopter Society.

Accounts of the various technical sessions presented during the annual meeting appear on other pages of this issue. Each of these write-ups has been prepared by the chairman of the session concerned.

▸ **Annual Business Meeting**—In accordance with the I.A.S. Constitution and By-Laws, the Institute's Annual Business Meeting was held on the last Wednesday in January, which this year fell on January 28. Several hundred members attended the business meeting in person; hundreds of others were represented by proxies.

The yearly reports of the President, Director, and Treasurer were read and approved. These reports were published in the March, 1953, issue of the AERONAUTICAL ENGINEERING REVIEW.

Pictures of the 1953 I.A.S. Council are on a succeeding page in this issue.

▸ **Publication of Papers**—Approximately half of the 53 papers presented during the course of the Twenty-First Annual Meeting were received by the Institute in sufficient time to be preprinted through the Sherman M. Fairchild Fund. Copies of those available in this form are listed on the Preprint Page of this issue (page 83).

Publication of most of the papers delivered at the annual meeting is scheduled for the earliest possible issues of either the JOURNAL OF THE AERONAUTICAL SCIENCES or the AERONAUTICAL ENGINEERING REVIEW.

LAST CALL for Roster Listings

A last call is being issued for required data for listings in the *1953–1954 I.A.S. Roster of Members*. Make sure that *YOUR* data card is filed immediately.

Air Power and New Weapons

GEN. HOYT S. VANDENBERG

Chief of Staff, U.S. Air Force

Honors Night Dinner Address

The other day, in *The New Yorker* magazine, I came across a cartoon that delighted me. It showed a small boy in a toy shop, climbing into a remarkable contraption labeled "space rocket." Behind him stands his mother, who says apprehensively, "I thought those things were still in the experimental stage."

I suppose that every generation in recent history has had to adjust itself to scientific developments affecting its habits of thought. But I doubt if mankind has ever

been more bewildered by such developments than is the case today.

I want to spend a few minutes discussing this situation and how the Air Force is trying to correct it—or, at least, trying to keep people from becoming more confused than they are already.

First of all, we must recognize that modern science has made enormous contributions to the art of war. Overshadowing all others, of course, is the atomic bomb, and the work in progress on the even more powerful thermonuclear explosive. The shock of our first knowledge that atomic warfare was an actuality was followed by a campaign to minimize the potential decisiveness of atomic weapons. This campaign reached its peak about 1949. Since then, it has declined greatly. Other military agencies have begun to share the Air Force's responsibilities for the delivery of atomic weapons.

Nevertheless, there is still a great deal of confusion about the relationship between these weapons and other scientific developments in warfare. The confusion is compounded by the claims and predictions, many of them conflicting, issued by various military organizations and arms manufacturers, who usually suggest that the new weapon or device they hope some day to perfect will supersede all others.

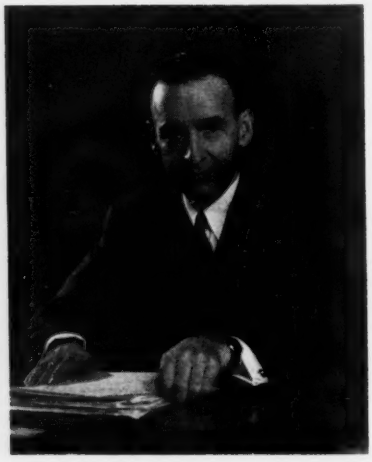
For example, not long after we proved the effectiveness of the atomic bomb and our means of delivering it, a military officer published an article that seriously argued that our best bet in war was to occupy the moon and use it as a base for operations against enemies on earth!

I do not ridicule this proposal. For all I know, it may truly come to pass that—in the language of the Old Testament—the moon and the planets will fight with us or against us. But I submit that we must keep these visions in perspective and consider them in order.

We have been deluged with predictions that certain vehicles of war will "soon" be atomic powered; that manless, automatic supermissiles will "soon" dominate the earth while orbiting platforms dominate outer space; or perhaps, more modestly, that some new kind of conventional projectile or some remodeled surface or subsurface vehicle will "soon" make everything else as out of date as a silk hat at Inauguration.

I do not mean to imply that fulfillment of any of these plans is impossible or even improbable. Permit me, however, to point out that they all contain a time equation that is scarcely resolved by the free use of the word "soon." Further, it has not escaped my atten-

(*Continued on page 82*)



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Vice-President
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Vice-President
George W. Brady
Director of Engineering
Propeller Division
Curtiss-Wright Corporation

Vice-President
C. L. (Kelly) Johnson
Chief Engineer
Lockheed Aircraft Corporation

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Joseph J. Maitan, Controller

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Consolidated Vultee Aircraft
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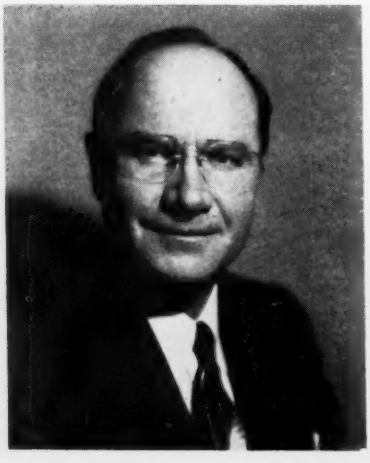
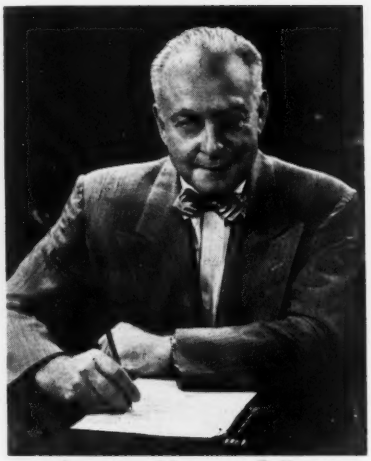




American Honorary Fellow
James Howard Kindelberger, Chairman of the Board and Chief Executive Officer, North American Aviation, Inc.

Honorary Fellows for 1952

Honorary Fellows shall be persons of eminence in aeronautics and are elected by the Fellows and Honorary Fellows of the Institute residing in the United States. Not more than one person residing in the United States, nor more than one person residing in a foreign country, may be elected as Honorary Fellows in any one year.

Foreign Honorary Fellow
Charles Clement Walker, Chief Engineer and a Founder Director, The de Havilland Aircraft Company, Ltd., England

Fellowships in the Institute

Fellows of the Institute of the Aeronautical Sciences shall be those who have attained a position of distinction in aeronautics and made notable and valuable contributions in one of the aeronautical sciences or aeronautical engineering.

Presented for 1952 to

Carlton Bioletti
Assistant Director, Ames Aeronautical Laboratory, N.A.C.A.

Philip A. Colman
Division Engineer, Aerodynamics, Lockheed Aircraft Corporation

G. H. Dowty
Chairman and Managing Director, Dowty Equipment Ltd., England

Louis G. Dunn
Director, Jet Propulsion Laboratory, California Institute of Technology

Frank W. Fink
Chief Engineer, Consolidated Vultee Aircraft Corporation

Captain John J. Ide
U.S.N.R., Aeronautical Consultant, N.A.C.A.

Peter Masefield
Chief Executive, British European Airways, England

Frank N. Piasecki
Chairman of the Board, Piasecki Helicopter Corporation

I.A.S. Awards and

Lt. Col. John P. Stapp, U.S.A.F. (M.C.), Chief, Special Projects Unit, Biophysics Br., A.M.L., W.A.D.C.

Vincent J. Schaefer, Scientist, Research Laboratory, General Electric Company, and Consultant.

The John Jeffries Award

This award honors the memory of Dr. John Jeffries, an American physician who, with Blanchard, the French balloonist, made the first aerial voyage across the English Channel in 1785 and on a previous voyage made the earliest recorded scientific observation from the air. This award, which has an honorarium of $200, was established by the Institute in 1940 to give recognition to the importance to aviation of scientific endeavor in the field of medicine.

Presented to LT. COL. JOHN P. STAPP, U.S.A.F. (M.C.)

"For outstanding contributions to the advancement of aeronautics through medical research."

The contributions for which Colonel Stapp has been cited resulted from a research program on "Human Tolerance to Abrupt Decelerations" which he conducted for the Aero Medical Laboratory between March, 1947, and June, 1951, at Edwards A.F.B., Calif. This program was instrumental in giving the aeromedical and aeronautical sciences hitherto unobtainable data on the degree of crash deceleration that a human can survive and in forming a sound foundation on which future research in this field could be based.

While this program was in progress, Colonel Stapp used himself as an experimental subject a total of 26 times in a specially constructed linear accelerator-decelerator. He personally demonstrated that man could tolerate decelerations as high as 46g's.

Using the data obtained during the 52 months of experimentation, Colonel Stapp was able to work out the principles governing man's protection against the forces of abrupt deceleration. He developed equipment and techniques that have increased the chances of human survival in aircraft crash landings. Since the conclusion of this program, the U.S.A.F. requirements for seat strength in fighter aircraft have been increased from 16 to 40g's (based on a 200-lb. man), strength of safety belts has been increased, and his modification of the standard U.S.A.F. harness is being readied for installation in fighter aircraft.

The Robert M. Losey Award

Established in 1940, this award honors the memory of Capt. Robert Moffatt Losey, a member of the Institute and a meteorologic officer of the Air Corps, who was killed at Dombas, Norway, April 21, 1940, while serving as an official observer for the U.S. Army. He was the first officer in the service of the United States to die in World War II. This award carries an honorarium of $200.

Presented to VINCENT J. SCHAEFER

"In recognition of outstanding contributions to the science of meteorology as applied to aeronautics."

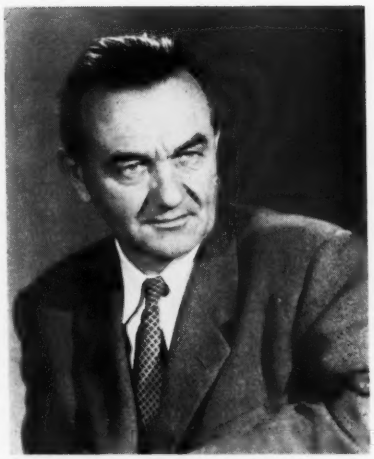
Mr. Schaefer, who has contributed variously to our knowledge of aircraft icing and precipitation static, made the significant discovery that particles of dry ice convert natural supercooled water clouds into ice nuclei, upon which water droplets in the clouds immediately crystallize to form snow crystals. This discovery, which has a direct bearing on the future of aviation, has led to important advances in our cognition of the mechanism of rainfall.

On November 13, 1946, Mr. Schaefer demonstrated his findings by transforming a cloud over Pittsfield, Mass., into snow streamers by seeding it from an airplane with dry-ice crystals. Subsequent experiments, conducted by Mr. Schaefer together with Irving Langmuir and Bernard Vonnegut, also G-E weather scientists, led to the conclusion that a dozen foreign materials, most notably silver iodide, are capable of acting as artificial nuclei for snow. Mr. Schaefer performed further experimentation along these lines in the initial stages of Project Cirrus.

Studies of weather modification have showed that cloud seeding holds great promise for modifying certain clouds, thunderstorms, and hurricanes, preventing hail, and dissipating ground fogs.

At this time, Mr. Schaefer is doing consultation work on an atmospheric project involving the jet stream. He is also continuing his study of cloud-physics and weather-modification techniques.

Honors for 1952



John Stack, Assistant Director, Langley Aeronautical Laboratory, N.A.C.A.

Dean R. Chapman, Aeronautical Research Scientist, Ames Aeronautical Laboratory, N.A.C.A.

The Sylvanus Albert Reed Award

For a notable contribution to the aeronautical sciences resulting from experimental or theoretical investigations which have had a beneficial influence on the development of practical aeronautics.

The late Dr. S. A. Reed, designer of metal aircraft propellers and a Founder Member of the Institute, made an endowment to the Institute in 1933 to provide an annual award with a certificate and honorarium of $250. The recipient of this award is chosen by the ballot of the American Honorary Fellows and Fellows of the Institute.

Presented to JOHN STACK

"For his leadership in the design, development, and practical operation of transonic wind tunnels."

The subsonic and supersonic wind tunnels are of limited value in the transonic speed range because of "choking." Accordingly, these tunnels afford only restricted transonic data on interesting, and at times critical, aerodynamic phenomena.

To overcome this situation, Mr. Stack instituted a series of intensive studies by teams of Langley investigators. A wind tunnel that could operate usefully at transonic speeds resulted. This vital research tool makes experimentation possible with standardized equipment, using nonexpendable models under conditions so closely controlled as to permit detailed measurements of local pressures, as well as application of optical means for visualization and measurements of flows.

The first large transonic wind tunnel was placed in operation at Langley; other N.A.C.A. transonic tunnels have since been completed. These tunnels, a reliable laboratory method for transonic experimentation, have served as prototypes and forerunners of other similar facilities now being installed elsewhere.

The Lawrence Sperry Award

For a notable contribution made by a young man to the advancement of aeronautics.

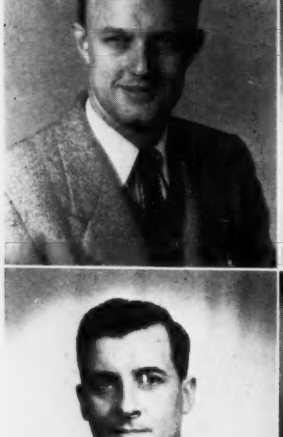
This award was endowed in 1936 by the sister and brothers of the late Lawrence Sperry, pioneer aviator and inventor, who died in 1923 at the age of 31. It provides an annual certificate of citation and an honorarium of $250 to the recipient selected by the Board of Award.

Presented to DEAN R. CHAPMAN

"For contributions to the basic knowledge of skin friction, base pressure, and heat transfer at supersonic speeds."

By taking the lead in establishing that the state of the boundary layer, and hence scale, is of real importance in determining pressure drag at supersonic speeds, Mr. Chapman added support to the cumulative evidence that supersonic wind tunnels—like subsonic wind tunnels—would need to simulate large-scale conditions. This conclusion has been far-reaching in the planning of supersonic wind-tunnel facilities and in the interpretation of supersonic wind-tunnel results.

Mr. Chapman then applied his boundary-layer studies to to the practical problem of flow and drag at the base of supersonic bodies. His results clarified and unified a body of experimental data and permitted the prediction of base drag. Applying these results to both supersonic bodies and wings, he ably defined the effects of trailing-edge bluntness. Finally, he made important contributions to the heat-transfer and skin characteristics of the supersonic boundary layer and has made experiments that provide high Mach Number skin-friction data greatly needed for the design of efficient missiles.



Newly Elected Members of the Institute Council

Eastern Area

Harris S. Campbell, Vice-President, Research and Development, Eastern Rotorcraft Corporation

Charles F. Savage, Assistant to Manager of Engineering, Meter & Instrument Department, Measurements Laboratory, General Electric Company

Central Area

Frank R. Cook, Director, Aeronautical Engineering, Minneapolis-Honeywell Regulator Company

Charles J. Gallant, Vice-President and General Manager, Columbus Division, North American Aviation, Inc.

Western Area

Frank A. Cleveland, Research Group Engineer, Preliminary Design Division, Lockheed Aircraft Corporation

J. R. MacGregor, Associate Director, California Research Corporation

Council Members

William B. Bergen, Vice-President and Chief Engineer, The Glenn L. Martin Company

Arthur E. Raymond, Vice-President, Engineering, Douglas Aircraft Company, Inc.

Rear Admiral Lawrence B. Richardson, U.S.N. (Ret.), Senior Vice-President, General Dynamics Corporation

Philip B. Taylor, Partner, Sanderson & Porter

Theodore P. Wright, Vice-President, Research, Cornell University

J. B. Rea Becomes Corporate Member

The J. B. Rea Company, Inc., of West Los Angeles, Calif., has joined the Institute of the Aeronautical Sciences as a Corporate Member. The Rea Company is an engineering firm that conducts research, development, and manufacture in the field of automatic control. During the relatively short period since its organization in March, 1951, a sizable number of research and development projects have either been successfully completed or are now under way.

Currently under development are a digital autopilot for airplanes and missiles, an automatic hovering control system for helicopters, an automatic cruise-control computer for long-range airplanes, and various systems related to underwater torpedo control and guidance. Plans are under way for the development of an automatic static strain-gage recording system (digital) and an automatic oscillograph record reader. According to the company's President, Dr. James B. Rea, many of these assignments have manufacturing potentialities, for which the company anticipates expanding its facilities. At present, the company has a well-equipped Electro-Mechanical Development Laboratory, including electronic laboratory equipment, and a Mechanical Model Shop. The company also has an experienced electromechanical design group and a highly qualified systems engineering analysis group.

Company personnel feel that this new organization has much to offer not only in its ability to assume direct responsibility for research and development of automatic control systems but also in providing consulting services to other prime contractors on the subject of automatic control. Consulting work has recently been completed with North American Aviation, Inc., Gilfilland Brothers, Chance Vought Aircraft Division of United Aircraft Corporation, and Beckman Instruments, Inc. Additional consulting work is planned with The Glenn L. Martin Company in the near future.

It should also be mentioned that the company does not expend all of its effort in Government work. In the commercial field, for example, research and development engineering is being conducted on the automatic control and stabilization of an oil barge for off-shore (tideland) drilling; research is also being conducted on a directional drilling computer for use in the oil industry; the automatic control of cooking ovens in the fish-canning industry is being studied; research is being conducted on the detection and control of the filtering efficiency in the processing of corn syrup; also, a study is being made on the application of automatic controls to aluminum production.

New men with excellent academic and industrial backgrounds are constantly being added to the staff, which now includes aerodynamicists, servomechanism engineers, instrumentation engineers, electronic engineers, mathematicians, structural engineers, chemists, and physicists.

P.A.L. Holds Documentation Seminars

Thirty-nine librarians, documentalists, and editors from business organizations and Government agencies in the Los Angeles area attended a series of seminars on the organization and utilization of specialized information. These seminars were given under the sponsorship of the Pacific Aeronautical Library and were held in the Los Angeles I.A.S. building from January 12–16.

The seminars were presented by Dr. Mortimer Taube, library consultant in the field of documentation and President of Documentation Incorporated, of Washington, D.C. Among the topics discussed in this series was Dr. Taube's approach to subject cataloging, which he calls "coordinate indexing." This particular system utilizes a subject card as the approach for obtaining information instead of the standard document card used in present library practices. This subject approach is said to eliminate the problem of direct or indirect headings, including "see also" headings.

The other topics covered by these seminars were: theory and practice of documentation; logic of organizing information; theory of classification and indexing; application of classification and indexing; and evaluation of classification and indexing.

I.A.S. Members Among M.A.A. Executive

At the annual meeting of the Manufacturers Aircraft Association, Inc., William E. Valk was re-elected President. Supporting him are six Vice-Presidents, three of whom are I.A.S. members. They are: Robert E. Gross, A.M.I.A.S., President and Chairman of the Board, Lockheed Aircraft Corporation; J. H. Kindelberger, H.F.I.A.S., Chairman of the Board, North American Aviation, Inc.; and Charles H. Chatfield, F.I.A.S., Secretary, United Aircraft Corporation.

The new Board of Directors for 1953 is composed of 15 persons. Of these, three are I.A.S. members: R. R. Osborn, F.I.A.S., Consulting Engineer, McDonnell Aircraft Corporation; G. C. Sullivan, M.I.A.S., Patent Counsel, Lockheed Aircraft Corporation; and Mr. Chatfield.

A.T.A. Forms Helicopter-Study Committee

A committee to study the feasibility of air-line use of helicopters was recently established by the authorization of the Board of Directors of the Air Transport Association of America. The membership of the committee has been drawn from air-line engineering, maintenance, and operating personnel, inasmuch as it was felt that in the initial phases of the study program the committee's work would be primarily concerned with the development of the design reliability and operating characteristics. At a later date, after an interim report and requisite recommendations have been submitted, traffic, scheduling, and ground-handling representatives will be appointed to the committee.

At the present time, the following persons compose the committee: J. J. Casey, of American Airlines, Inc.; Charles Froesch, F.I.A.S., Vice-President—Engineering, Eastern Air Lines, Inc.; A. A. Lane, of Northeast Airlines, Inc.; David E. Postle, of Mohawk Airlines, Inc.; H. J. Reid, of Capital Airlines, Inc.; and Robert W. Rummel, M.I.A.S., Chief Engineer, Trans World Airlines, Inc.

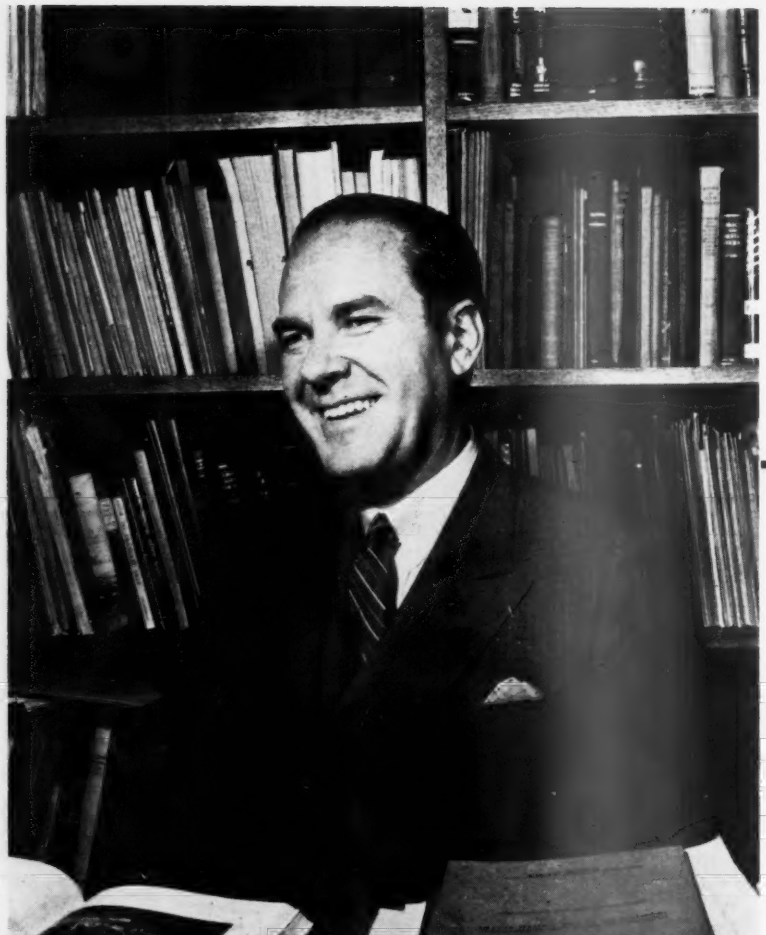
Mr. Froesch is acting as Temporary Chairman. Grahame Aldrich, of A.T.A., is the Consultant for the committee, and Donald B. Talmage, M.I.A.S., of the A.T.A. Engineering Division, is Secretary.

News of Members

▸ **Malcolm J. Abzug** (M.), Design Specialist, El Segundo Plant, Douglas Aircraft Company, Inc., has been appointed to the N.A.C.A. Subcommittee on Stability and Control.

▸ **The Right Honourable Lord Brabazon of Tara** (M.), Chairman, Air Registration Board, Great Britain, received the Knight Grand Cross of

(*Continued on page 87*)



Dr. Ross A. McFarland, Associate Professor of Industrial Hygiene of the Harvard School of Public Health, has been one of the principal exponents of the study of the physical and psychological environment of airplane pilots. He is working toward flight safety in a field that is of major importance to airplane designers and airplane operators. His recently published book *Human Factors in Air Transportation—Occupational Health and Safety* (McGraw-Hill Book Company, January, 1953) is an important contribution to the literature in this area. It will be reviewed in a later issue.

Editorial

Deus ex Machina

In retrospect, one of the most striking aspects of the Institute's Twenty-First Annual Meeting was the higher-than-average attention given to that least predictable element in all engineering calculations—the Human Animal. Not only in many of the Technical Sessions (some of which are referred to in detail on the following pages) but in many of the discussions that were offered up with the several luncheons, dinner, etc., the focus of attention was on Man more than on Machinery.

General Vandenberg mentioned the continuing and intensive research to reduce the load on the human pilot but conceded that he was here to stay—for a long time. Dr. Furnas in his forecast for the next 50 years made the point that guided missiles (and all other such devices) are essentially stupid. They lack the element of judgment that man with his complex nervous systems of billions of memory-storing cells comes by naturally. And when it comes to servomechanisms (devices to react in response to a set of complicated and rapidly changing stimuli) P. R. Bassett could see nothing in being, or in prospect, to replace the human body. Dr. Stovall, speaking from the standpoint of the medical profession, said that "human error is the principal cause of deviations from operational efficiency" and deduced the need for an extensive program to study all phases of human participation in aviation activities.

So, from the point of view of the I.A.S., it is increasingly evident that we are fully justified in spending more time studying the human factors in engineering than we have in the past. The day when the pilot goes along just for the ride to keep a watchful eye on the health and well-being of the Genii (or perhaps Gremlins!) which live in the Little Black Boxes is not yet at hand. This is the reason why General Benson was asked to pull together the symposium that is reported in this issue. This is the reason why the I.A.S. has a more than casual interest in the activities of the Flight Safety Foundation and The Daniel and Florence Guggenheim Aviation Safety Center at Cornell University. This is the reason why an increasing percentage of our technical sessions must be devoted to problems of human behavior.

No matter how well we do our work as engineers, no matter how ingenious the devices may be which come out of our research and development programs, in the end it is always a human being who is responsible for their operation and on whom the lives of many other human beings ultimately depend. There is no question but that scientific studies of why humans who fly aircraft behave as they do fall within the proper purview of the I.A.S.

But abstract discussion of pilot behavior is only the first step. We, as designers, cannot make our aircraft absolutely foolproof. (That could be done only by anchoring them firmly to the ground and surrounding them with high fences!) We must, however, design them so that it is easy for the human pilot to do the right thing at the right time without undue strain. We must design them so that the people who maintain them can never do the wrong thing at any time without being aware of it. We must design them so that our customers, the traveling public, will prefer the airplane over any other mode of transportation. The only way that can be done is to keep *safety* always in mind from the first design concept to the day when any particular airplane is finally "turned out to pasture."

S. P. J.

I.A.S. 21st Annual Meeting

Summary of Technical Sessions

MORE THAN 1,200 MEMBERS of the Institute and co-operating societies registered for the Technical Sessions of the Annual Meeting at the Hotel Astor in New York, January 26–29. In addition to the 53 papers presented, three splendid luncheon talks and two symposiums added much to the wealth of aeronautical information disseminated at the meeting.

Most of the papers presented will be published in the REVIEW or JOURNAL at the earliest possible dates. Preprints of some of the papers are immediately available. Information about these may be found on the Preprint Page (page 83).

All eight of the papers presented during the Aviation Medicine Session have been published in this issue. The special Electronics Issue for May will contain a complete round-up of the discussions presented during the symposium sessions, plus the four papers given on the "Impact of Electronic Trends on Aircraft Design."

The editors are indebted to most of the chairmen of the individual sessions for the following reports.

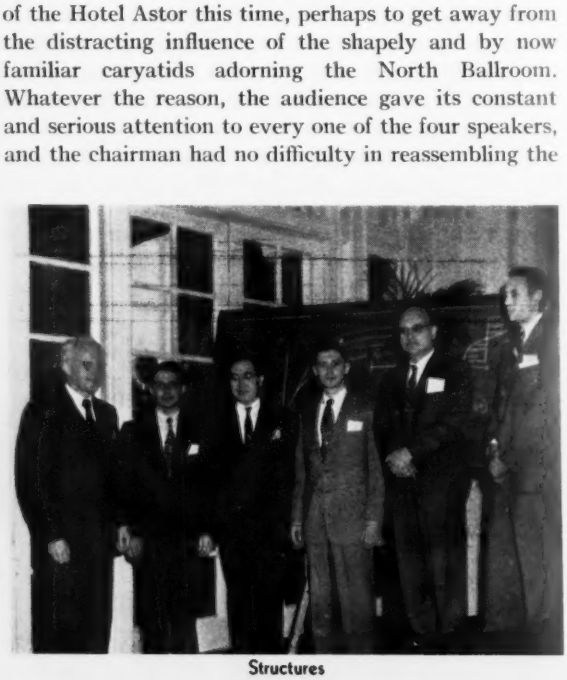
Structures

By

Walter Ramberg

Chief, Mechanics Division, National Bureau of Standards

The Structures Session was held in the East Ballroom of the Hotel Astor this time, perhaps to get away from the distracting influence of the shapely and by now familiar caryatids adorning the North Ballroom. Whatever the reason, the audience gave its constant and serious attention to every one of the four speakers, and the chairman had no difficulty in reassembling the Session after the usual intermission following the second paper.



Structures

The Session was opened with the presentation by Prof. S. V. Nardo, Polytechnic Institute of Brooklyn, of his paper on "An Exact Solution for the Buckling Load of Flat Sandwich Panels with Loaded Edges Clamped." In this paper Professor Nardo solves the differential equations derived by N. J. Hoff (*N.A.C.A. T.N. No. 2225*, November, 1950) for a sandwich panel having a core of finite shear rigidity when this panel is loaded in end compression and the two edges under load are clamped while the other two edges are simply supported. Numerical solutions for the buckling stress are plotted for panels with aspect ratios b/a ($2a$ = length of loaded edge, $2b$ = length of unloaded edge) ranging from 0.8 to 3.8 and ratios $R = 12(1 - \nu^1)Ga^2/Et^2$ of rigidity in shear to rigidity in bending (G = shear modulus of core material, E = Young's modulus of facing material, t = thickness of each facing sheet) ranging from 1,000 to 50,000. It is shown that the buckling load is equal within 20 per cent to that for a panel with simply supported edges all around, provided that b/a is greater than 2. The shear deformation of the core lowers the buckling stress approximately 50 per cent as R is decreased from 10,000 to 1,000. The computed buckling loads were found to agree within 20 per cent with experimental values obtained at the Forest Products Laboratory. The discussion of the paper concerned itself with ways of expediting the solution of the buckling determinant for the problem.

The second paper was "Deflections of Beams and Columns" by Y. Pao and J. Marin, both of The Pennsylvania State College. It was presented by the first author. In the paper equations are derived to take account of recovery, as well as creep, in the stress analysis of beams and columns. The strain ϵ is assumed to be related to the stress σ and permanent strain ϵ_p' by the expression

$$\epsilon = \frac{\sigma}{E} + \int_0^t 9(K\sigma^n - \epsilon_p') \, dt + \int_0^t B\sigma^n \, dt$$

where E is Young's modulus, t is time, and q, K, n are empirical constants. The first term on the right of this expression is the elastic strain, the second is the transient creep strain, and the third is the linear creep strain. From this expression a general solution was obtained for the stress distribution in a pin-ended column with initial eccentricity, on the assumption that plane sections remain plane and that the extreme fiber stress in the column could be expressed as the product of two functions, a function of time and a function of distance along the column. It was also applied to the case of a

cantilever beam deflected by a transverse load at the free end. The stress distribution across a given section is represented in both cases by $\sigma = \sigma_1(y/h)^{1/n}$. Since the theory makes allowance for recovery, it can be used to estimate creep in the presence of decreasing, as well as increasing or constant, loads or bending moments. In the discussion some question was raised regarding the assumption that the shape of the deflection remains fixed with time during creep in a column.

The third paper was entitled "Stress Analysis of Sheet Stringer Panels with Cutouts" and was presented by Harvey G. McComb, Jr., of the N.A.C.A. Mr. McComb described a novel perturbation method for computing the change in stress in a stiffened sheet due to the introduction of a rectangular cutout. The sheet is assumed to be stiffened by stringers of zero bending stiffness and of finite axial stiffness and by ribs that prevent transverse displacement but offer no restraint to longitudinal displacement of the stringer. The sheet is assumed to carry only shear stresses, while the stringers carry only direct stresses. The effect of the cutout is replaced by that of local forces of three different types. Extensive tables are given in the paper to show the stress distribution throughout the structure due to a unit force of each type and for various values of a reinforcement parameter

$$B = (E/G)A/bt)(b^2/L^2)$$

(E = Young's modulus, G = shear modulus, A = area of stringers, b = stringer spacing, t = sheet thickness, and L = distance between ribs.) It is shown how solutions for the stress distribution around a given cutout in a given structure can be obtained quickly from these tables and how one can account for reinforcement around cutouts in which the thickness of the sheet or the area of the stringers is increased around the cutout.

Professor P. P. Bijlaard, of Cornell University, presented the last paper entitled "Compressive Buckling of Plates Due to Forced Crippling of Stiffeners" prepared by him and G. S. Johnston, of Bell Aircraft Corporation. The analytical part of this paper concerns itself with the difficult problem of computing the buckling stress for sheet riveted to stringers in a sheet stringer panel or to beam flanges in a multiweb beam in which the buckles in the sheet continue across the stiffener and force the stiffener flange to distort locally. Tests had shown that the buckling load under these conditions was sometimes as much as 70 per cent below that computed from the conventional analysis, which neglects the flexibility of the stiffener. In the analysis the sheet riveted to the stiffener is treated as a plate supported by an elastic medium with different spring constants in the upward and downward directions. The spring constants themselves are determined by considering the deflection of the stiffener under the action of a sinusoidal load applied by the sheet. The results of the analysis are presented in the form of design charts for the allowable stress for the "forced crippling mode." A simple procedure is outlined for estimating the buckling stresses beyond the elastic range. Inside the elastic range the theoretical buckling stresses for forced crippling can be approximated roughly by

$$\sigma_{cr} = 0.6\, E(t_s/b_a)/(t/b)$$

where E = Young's modulus, t_s = thickness of stiffener flange, b_a = distance from rivet line to middle plane of stiffener web, t = sheet thickness, and b = stiffener spacing. Comparison with test results for nine specimens showed that the computed buckling stress differed less than 10 per cent from that measured in all except one case.

The Session closed with a general feeling that, brief as it was, it had touched on, either in the papers or in the discussion, most of the interests of structures men whether these lay in the field of design, numerical computation, elasticity, plasticity, stability, or properties of materials.

Flight Propulsion

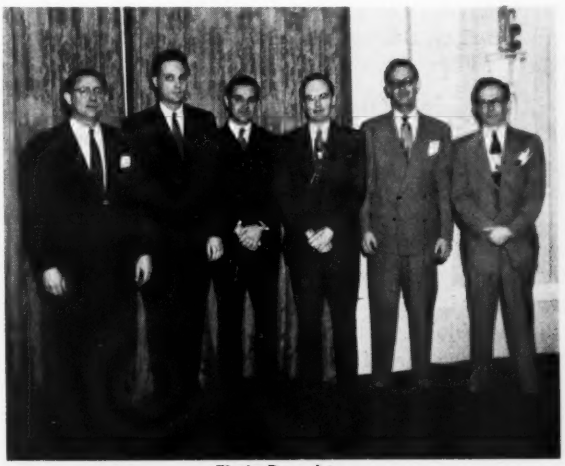
Internal Aerodynamics of Gas Turbines

Abe Silverstein, Chairman

Associate Director, Lewis Flight Propulsion Laboratory, N.A.C.A.

Stall-Flutter in Cascades, by Fernando Sisto, Wright Aeronautical Division, Curtiss-Wright Corporation. Assuming the complex of aerodynamic reactions to be small compared with blade inertia and elastic forces, some results from nonlinear mechanics are utilized to develop a convenient method of studying stall-flutter oscillations. This represents a new method of attacking the problem.

Data are presented from an exploratory experimental investigation in a "two-dimensional" cascade in which one blade and later three blades are flexibly mounted. The variation of flutter amplitude with stream velocity and mean incidence is obtained for angles of attack near the static stall. Experimental determinations are given for three different gap/chord ratios. The motion is predominantly torsional.



Flight Propulsion

The results confirm certain deductions from the nonlinear theory concerning transient behavior and equilibrium flutter amplitudes, or "limit-cycles." The effect of cascading is consistent with the assumed stall-flutter mechanism. Other qualitative results are reported which confirm the essentiality of adopting this general approach in order to explain the gross features of stall-flutter phenomena.

Propagation of Stall in Compressor Blade Rows, by Frank E. Marble, Assistant Professor, Guggenheim Jet Propulsion Center, California Institute of Technology. It has been observed that the transition from normal compressor operation to stalled operation is not a simple process of flow breakdown on each of the blades of a given blade row but is rather more complicated in that stall initially takes place over only a small group of blades in any blade row. The flow is therefore no longer axially symmetric. It is observed further that not always the same group of blades is involved but that the stalled region moves from one group of blades to another with a certain characteristic velocity, giving rise to the term stall propagation or, more graphically, the rotating stall. The present paper considers a model of the phenomenon based, as is the recent work of W. R. Sears, upon nonstationary airfoil theory, employing an assumed dynamic stalling performance of the airfoil cascade.

The stall propagation speed, steady and oscillating blade forces are calculated for a single blade row. The results exhibit the character generally observed in experiment. The analysis is then extended to two adjacent blade rows in relative motion, such as a stator and rotor combination. The influence of mutual interference upon the speed of stall propagation, steady and fluctuating blade loads may be strong depending upon the geometry and velocity diagrams for the two rows. Using these results, the process of approaching and entering the state of rotating stall is discussed for a compressor utilizing an external throttling mechanism.

Finally, the three-dimensional effects are discussed. The observations that a propagating stall may occur which involves only a portion of the blade height are examined on the basis of a three-dimensional cascade theory.

Aerodynamic Interference Between Moving Blade Rows, by Nelson H. Kemp, Graduate Student and Research Assistant, and W. R. Sears, Director, Graduate School of Aeronautical Engineering, Cornell University. This is a brief report on an investigation of the unsteady aerodynamic effects in a typical stage of an axial turbomachine, caused by the relative motion of the stator- and rotor-blade rows. The problem is attacked from the standpoint of the theory of thin airfoils in nonsteady, incompressible, inviscid flow.

Here the stage consists of an infinite row of two-dimensional stator blades followed by an infinite row of moving rotor blades. The method of analysis is an approximate one, based on the assumption that the nonsteady part of the circulation about any blade is small compared to the steady part, the latter being the only part ordinarily considered by the designer. The results include expressions for the nonsteady components of lift and moment on stator and rotor blades, expressed as ratios to the steady values. The rate of transfer of energy to the downstream wake pattern, which is caused by the fluctuations of the blade circulations, is also obtained.

Numerical results are presented for some typical configurations representing compressor stages. From these examples it appears that the nonsteady forces may be of appreciable magnitude (e.g., 18 per cent of the steady values), especially when the entry of the rotor blades is not "shock-free." The magnitudes of unsteady effects depend strongly on the distance between the blade rows.

Stall and Surge in Axial-Flow Compressors for Jet Engines, by M. C. Huppert and W. A. Benser, Lewis Flight Propulsion Laboratory, N.A.C.A. Observations of rotating stall have shown that a wide variety of stall patterns is possible. Hot-wire anemometer data on a multistage compressor have shown a progressive-type stall at low speeds. The amplitude of the flow fluctuations increases in magnitude through the first few stages and then diminishes rapidly to a small value in the latter stages. A stage stacking analysis has shown that rotating stall will exist over a large portion of the compressor map at low speeds but will be instigated almost simultaneously with compressor surge at high speeds.

Blade failures attributable to resonant vibrations excited by rotating stall have been experienced in single- and multistage compressors.

In the stage stacking analysis no deterioration of stage performance due to unsteady flow resulting from stall of adjacent stages was considered. In general, the pressure drop at the stall point is believed to be much larger than indicated by an analytical formulation of compressor performance. Compressor surge is attributed to a limit cycle operation about the compressor stall point, and, as indicated in a few compressor tests and in jet-engine tests, a small compressor discharge receiver volume may result simply in stall of the compressor without the cyclic characteristics of compressor surge. In this event, engine operation will be limited because of the large drop in performance which accompanies compressor stall.

Aircraft Design

F. K. Teichmann, Chairman

Professor and Chairman, Department of Aeronautical Engineering, Guggenheim School of Aeronautics, New York University

Some Basic Concepts for Analyzing Dynamic Flight-Test Data, by Harold Klein, Aerodynamics Engineer, and Raymond Sedney, Aerodynamicist, Douglas Aircraft Company, Inc. The problem considered here is that of finding through the use of observed data the

coefficients of the differential equations that describe a dynamic system. This problem occurs in the determination of the aerodynamic stability derivatives of an airplane or missile from flight-test data. There is a maximum number of coefficients which may be determined. A method is given for finding this number, and conditions are given under which the maximum number is obtained. These results are summarized in a working rule and applied to two examples. It is shown that the free-oscillation type of flight testing can never yield all the coefficients. Suitable forcing functions are described which do permit all coefficients to be evaluated.

The Structural Tail-Load Problem—Theory, Tests, and Criteria, by Richard K. Koegler, Head, Engineering Branch, Flight Research Department, Cornell Aeronautical Laboratory, Inc. Unclassified literature on this problem relative to conventional subsonic aircraft is reviewed. However, the conclusions reached have general applicability.

Tail loads can be satisfactorily determined for structural design purposes from present linear stability and control equations and calculation methods for all cases except those involving extreme angular excursions. Accuracy is dependent largely on accuracy of stability derivative determination.

Currently existing and proposed horizontal tail-load criteria fall into three general categories, each of which has certain advantages. Statistical data on time histories of load factors or motions are needed in all three cases. Such data, if correlated with stability characteristics, could lead to simple rational criteria.

Vertical tail-load criteria require statistical data on loads and maneuvers for further improvement, and a possible simple recorder for this purpose is discussed. A study of complete equations of motions for rolling pull-out calculations is discussed.

Literature on spanwise distributions of horizontal tail loads shows that a reduction in loading near the fuselage should be assumed. Asymmetrical loadings are briefly mentioned.

Literature on buffeting shows its prevalence and significance. Recent studies of rational methods of treating this problem are discussed briefly relative to needed data and possible applications.

Aeroelasticity and nonstationary aerodynamic effects are briefly discussed.

Notes on the Analysis and Design of Multipost Stiffened Wings, by D. M. Badger, Group Leader, Structures Research and Development Group, Northrop Aircraft, Inc. This paper discusses an unconventional type of wing construction which utilizes spanwise rows of vertical posts to stabilize the compression skin against buckling by tying it to the inherently stable tension skin. This construction offers two manufacturing advantages: (1) additional working space gained through the openings between the posts and (2) fewer internal fasteners necessary to attach posts as compared to shear webs.

Aircraft Design

Stringers installed along the lines of posts are needed to achieve high buckling strengths and to prevent an undesirable type of buckling involving both tension and compression skins. However, these stringers need be only one-tenth as stiff as stringers acting alone.

The basic concepts that should be understood before design optimization is attempted are covered in this paper. Theory recently developed by the N.A.C.A. is interpreted, and the results of large-scale static tests conducted at Northrop Aircraft, Inc., to substantiate the design of a complete poststiffened wing are discussed.

Military Air Cargo Carrier Trends, by Walter Tydon, Chief Engineer, Aircraft Division, Fairchild Engine and Airplane Corporation. This paper deals basically with the operational trends as they affect component and system designs, where speed becomes only one factor, with other more important factors being turn-around-time and ability to deliver to final destination. The fuselage design, with its trend toward high wing, is being more and more influenced by larger units of cargo, not only from the standpoint of ground handling but from aerial delivery, which has been successfully operated up to 21,000 lbs.

Advance base operation has also had a marked influence on cargo types with its requirements for low take-off and landing distances, low-speed stability and control, rough field gear, simplified loading, and need for lower turn-around-time. With these have come such accepted features as cockpit emergency egress hatches; external fuel with its advantages of safety, wider c.g. cargo range, and ease of refueling, service, and repair; and structural requirements for crash landings.

The detachable pack is an inevitable part of the trends, with its advantages of reduction in terminal facilities and handling methods and equipment leading to substantial reduction in turn-around-time. Current aerial delivery problems are lessened with increased efficiency and accuracy. Safety by jettisoning the entire pack is an important military advantage.

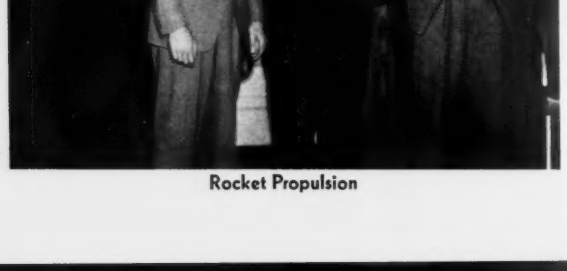
Rocket Propulsion

By
F. C. Durant, III
Arthur D. Little, Inc., and President, American Rocket Society

The American Rocket Society cooperated with the I.A.S. in presenting a technical session on rocket propulsion on January 26, 1953. The occasion was the opening day of the four-day I.A.S. Annual Meeting held at the Hotel Astor, New York. Three papers were presented covering widely separated fields of investigation related to rocket propulsion, with 130 persons in attendance.

The first paper, entitled "The Effect of Fluid Properties on the Spray Formed by Two Impinging Jets," was presented by R. J. Priem. The paper described a program of basic research in which the fluid properties of a spray formed by two impinging jets were studied. Four different spray shapes were obtained using glycerol-water mixtures and hydrocarbon oils. Photographs of these four shapes are shown in Figs. 5–8. The conditions under which these different sprays were formed, together with their apparent properties, were presented. It was found that the length of the spray before breakup into droplets was dependent upon fluid properties but that the maximum width of the spray was unaffected by fluid properties. Excellent high-speed photographs of the spray patterns, together with curves of results and diagrams of apparatus layout, were included. Mr. Priem, together with the paper's coauthor M. F. Heidmann, are research engineers at the Lewis Flight Propulsion Laboratory, N.A.C.A., Cleveland.

The second paper, entitled "Earth-Scanning Techniques for Orbital Rocket Vehicles," was presented by its author, Kurt R. Stehling. Two possible methods of utilizing an earth satellite vehicle to gather and transmit information about the earth's surface were examined. One of these methods utilized an optical objective lens image-converter system; the other, a microwave scanner. Assumed were a vehicle flight altitude



Rocket Propulsion

SPRAY FORMATION "A"

Figure 5.

SPRAY FORMATION "B"

Figure 6.

SPRAY FORMATION "C"

Figure 7.

SPRAY FORMATION "D"

Figure 8.

of 500 miles, orbital velocity of 5 miles per sec., a hypothetical target of 600 yards diameter, and restricted design requirements of a minimum weight satellite vehicle pay load.

It was shown that the net resolving power of the optical-video system is limited not by the optical train but by the image converter and available transmission bandwidth; the effects of the atmosphere, meteorological conditions, and albedo were also discussed. The approximate resolving power, weight, and power and space requirements of a microwave radar scanning unit were outlined, and the advantages and disadvantages of this system were weighed.

Mr. Stehling believes that, with the present state of radar scanning (which can be discussed on an unclassified status), the optical system has the weight and resolving power advantage, but its daylight dependence and atmospheric and cloud attenuation limitations are severe enough to indicate questionable feasibility. Furthermore, the low resolving power of a radar unit, from the 500-mile altitude, and the attenuation losses tend to limit the usefulness of this system.

It was generally concluded that the discussed earth-scanning techniques for the location of the indicated target size may not be practical for a small instrumented orbital vehicle. The substitution of a human observer for some of the instrumentation might result in a weight-saving despite the requirements of food and air.

The presentation was enlivened by a number of excellent slides graphically portraying different scanning systems and their operation. Mr. Stehling is Rocket Research Engineer at Bell Aircraft Corporation, Buffalo, and a member of A.R.S. Space-Flight Committee.

The final paper, entitled "Measurements in Rocket-Engine Testing," was presented by Howland B. Jones, formerly with Reaction Motors, Inc. This presentation covered the application of conventional and special instrumentation equipment to the static testing of (liquid-propellant) rocket engines. In his introduction, Mr. Jones discussed peculiarities of this testing field, including accuracy limits and need for transient, as well as static, measurements. The conventional quantities of pressure, flow, force, temperature, linear and angular displacement, and vibrational acceleration were then treated, as well as modifications to conventional measuring equipment and specially designed instruments. Of particular interest were Mr. Jones's descriptions of: a multichannel pressure recording unit operating into a single cathode-ray tube, a combination of a four-gun cathode-ray oscillograph and tape recorder, and use of a conventional sonic analyzer with associated equipment.

Aerodynamics—I

By

Charles E. Mack, Jr.

Chief of Research, Grumman Aircraft Engineering Corporation

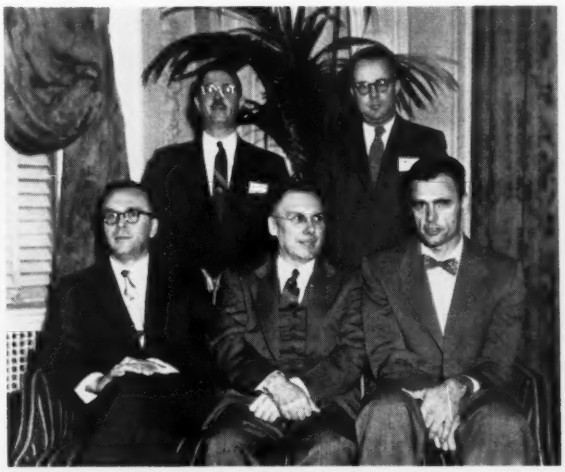
The opening Aerodynamics Session was concerned with flow phenomena in a viscid fluid and was one of the best attended sessions of the entire meeting. This is evidence of the ever increasing importance that this field of aerodynamics is assuming in connection with the design of modern aircraft. As higher and higher supersonic speeds are sought after, the question of aerodynamic heating (to name just one of many serious problems) becomes of paramount importance. The so-called thermal barrier—where the temperature may be of the order of 1,000°F. or more—appears as a formidable obstacle to safe flight in the extremely high speed range. The need for basic understanding of the physical processes involved and accurate experimental data for the use of designers in this region is apparent.

Of the four papers presented in this session, two were in the nature of reviews of the literature and the other two were essentially concerned with experimental matters. The titles and authors of the papers are listed below in the order in which they were presented, together with a few remarks concerning some of their salient features.

(1) **Survey of Friction Coefficients, Recovery Factors and Heat-Transfer Coefficients for Supersonic Flows,** by Joseph Kaye, Massachusetts Institute of Technology. In this paper the recent literature concerning the three coefficients mentioned in the title is reviewed and compared in detail with the corresponding theoretical work for both laminar and turbulent boundary layers. Unfortunately, wide gaps still exist in the available experimental data for some of these coefficients for various combinations of Mach and Reynolds Numbers. Nevertheless, the overall conclusion is that the agreement between theory and experiment is fairly good for both laminar and turbulent boundary layers as far as skin-friction coefficient and recovery factors are concerned for moderate Mach Numbers. There is still much work to be done on heat-transfer coefficients.

As a partial answer to this lack of heat-transfer measurements, Professor Kaye gave an interesting description of two research projects in this field currently being carried out at M.I.T., one under the sponsorship of the Office of Naval Research and the other sponsored by the Office of Air Research. The primary purpose of the O.N.R. project is to obtain reliable data on the rate of heat transfer to air moving at supersonic speeds in a round tube. The objective of the O.A.R. project is similar except that the air moves over a flat plate. Both of these investigations are for Mach Numbers up to about 3.

(2) **Direct Force Measurements of Turbulent Skin Friction on Cylinders in Axial Flow at Subsonic and Supersonic Velocities,** by Dean R. Chapman and Robert H. Kessler, Ames Aeronautical Laboratory, N.A.C.A. The paper was presented by Dr. Chapman. Aside from the utilitarian value of data of this kind, one of the reasons that the research reported on in this paper was initiated is that the numerous theories for calculating turbulent skin friction give widely different results, and it was desired to find out which of them (if any) could be verified experimentally. The measurements were made on several cone cylinders with fineness ratios of 10, 15, and 25 and for Mach Numbers between 0.5 and 3.6 (Reynolds Numbers from 4×10^6 to 36×10^6). It was found that four of the 15 available theories agreed with the measurements within 5 per cent both subsonically and supersonically. Dr. Chapman pointed out, however, that for hypersonic Mach Numbers these same theories give widely scattered results so that extensive additional measurements at these high Mach Numbers are clearly necessary.



Aerodynamics—I

(3) **Turbulence in Supersonic Flow,** by Leslie S. G. Kovasznay, The Johns Hopkins University. The subject matter of this paper was not quite so broad as its title might indicate—it was fundamentally a discussion of the principal instrument used for measuring turbulence in compressible flows, the hot-wire anemometer. Professor Kovasznay defined what he termed "modes" of fluctuation, three in number: temperature spottiness, turbulent velocity fluctuations, and ordinary sound waves. There is interaction among all of these "modes," but fortunately the hot-wire anemometer responds in a different manner to each of them. Various fluctuation diagrams—which to the inexperienced might appear to resemble "hash" on an ordinary oscillograph record obtained in flight tests, for example—can be obtained by operating the instrument at different temperatures and in this way the individual "modes" identified. Professor Kovasznay pointed out that, in the usual case, all three "modes" are likely to be important.

(4) **Review of Published Data on the Effect of Roughness on Transition from Laminar to Turbulent Flow,** by Hugh L. Dryden, Director, N.A.C.A. In this paper, which concerns itself with a fundamental question in aerodynamics, nine references are quoted including one recent Japanese investigation not yet published. One of the important conclusions that Dr. Dryden draws from his reanalysis of the data is that the transition Reynolds Number of a flat plate with a single roughness element is chiefly a function of the ratio of the height of the element to the boundary-layer displacement thickness at the element. It was also concluded that the effects of roughness are approximately the same in flows containing different amounts of initial turbulence. In addition to considerations of a single roughness element, Dr. Dryden discussed available data on distributed roughness both for a flat plate and for airfoils.

One noteworthy feature of the session, in the Chairman's opinion, was the use made by all the speakers of numerous slides. These slides were, in almost every instance, of adequate size and clarity. Many of them were photographs of equipment, and as such they were much more satisfactory than purely verbal descriptions or schematic diagrams on the blackboard.

Aerodynamics—II

By
Courtland D. Perkins
Department of Aeronautical Engineering, Princeton University

In the Second Session on Aerodynamics, four papers were presented covering a rather wide field of interest. These papers included the results of research on airplane response characteristics in low-speed landing approaches, some problems of missile dynamics, and two papers involving problems of supersonic flows—the first dealing with the effect of streamwise gaps on lift and pitching moments of supersonic aircraft and the second

Aerodynamics—II

on the problem of supersonic flows past slender bodies of elliptical cross section.

The first paper was written by two members of the Stability Research Division of the National Advisory Committee for Aeronautics, Langley Aeronautical Laboratory Staff. The paper was entitled "Study of Some Effects of Airplane Configuration on the Response to Longitudinal Control in Landing Approaches," and the authors were Ralph W. Stone, Jr., and William Birhle, Jr. Mr. Stone read the paper. In this paper the authors point out that the present trend toward heavily sweptback-wing aircraft of low aspect ratio and, in many cases, with no horizontal tail has lead to handling characteristics that seem considerably different to pilots undergoing the experience of flying them for the first time.

The authors correctly point out that the response characteristics of new configurations in terms of pilot reactions to flying them is somewhat clouded through such factors as range of vision, control feel, time lags, and actual psychological aspects. This, of course, has always been the case when any new developments in aircraft configuration came along. The pilots first undergoing the experience of flying airplanes of abnormally high wing loading or with high lift flaps involving large attitude changes have always felt that the handling qualities were adversely affected at the start. However, they soon became used to these conditions and considered the less good handling qualities as something to be expected and actually what might be considered normal. This same uncertainty will exist when the deltas and other strange configurations, especially those with no horizontal tails, first get into the service in any quantities. The authors of this particular paper have dealt with one aspect of this problem—that is, the time lag involved in pitching the airplane in response to its elevator control and the subsequent control of the vertical position of the airplane during low-speed approaches.

The study was made on the analog computer and involved solutions to the normal longitudinal

equations of motion following a prescribed pattern of control disturbance felt to be somewhat typical of what a pilot might experience during a landing approach. The solutions obtained were rather clear on the point that the newer configurations will have less control of height and the time lags will be larger. This is in large measure due to the lower control power of the trailing-edge flap elevator on tailless deltas, combined with the adverse effect on the lift of control surface deflection. The variation of the effectiveness of the different airplane configurations to control their height and the effect of these parameters on the airplane's time lag are rather neatly presented and give a clear insight into the problem. Discussion after the paper pointed out the fact that other parameters must be investigated to find out what the overall picture or overall problem is, and only time will tell if the pilots of what we consider today as a rather strange aircraft will at some later date consider their characteristics to be expected and normal.

The second paper, presented by John A. Nicolaides, Aerodynamicist, Ballistic Research Laboratories, Aberdeen Proving Ground, was "On the Free Flight Motion of Missiles Having Slight Configurational Asymmetries." Mr. Nicolaides pointed out at the outset that a better theory was required to account for the motions of missiles in order to predict the rather strange characteristics of these missiles with regard to dispersion, tumbling, and other strange flight motions that have been observed on statically stable and otherwise generally well-behaving missiles. He pointed out that the normal equations of motion used by the aerodynamicists involving separate problems of longitudinal and lateral motions could not be used on missiles, especially those that are rolling or have a built-in asymmetry. Also, the ballistic expert is normally concerned only with rapidly rolling symmetrical missiles. Mr. Nicolaides felt that it was time someone took in hand the problem of writing down the complete equations of motion to cover this whole problem and put it in terms of aerodynamics nomenclature. He presented such equations that account not only for the symmetrically statically stable missiles but also one that could keep rolling or also contain a slight amount of asymmetry due to control surface deflection, wing and tail incidence, bent body, etc. These equations yield the conditions for dynamic stability for both statically unstable missiles and also predict that the configuration asymmetry, used together with rolling velocity, may result in response instability.

The motions of the missiles developed in this theory have been checked on at least two models of simple arrow-type configuration when gun-launched at supersonic velocities in the Aberdeen Spark Photography Range in which the motion of the missiles could be obtained versus time, pitching, yawing and in transverse displacement. The results of this experiment show that in at least two of the tests it was possible to check the theory accurately and determine the aerodynamic derivatives therefrom. The author pointed out that this work was going to be continued on an experimental basis in the Aberdeen Spark Photography Range in order to verify further the theory presented in this paper. This paper was extremely interesting, and it was of interest to all that the excellent research tool, the Aberdeen Spark Photography Range, was continuing to be used for this important research purpose.

The third paper, "Some Aerodynamic Effects of Streamwise Gaps in Low Ratio Lifting Surfaces at Supersonic Speeds," was written by two members of the Aerodynamics Section of Douglas Aircraft Company, Inc., at Santa Monica, Drs. Z. O. Bleviss and R. A. Struble. As trends in modern aircraft design progress, it seems that the wings are getting smaller and smaller with respect to the fuselage. This is, of course, especially true in all missile design work and brings to the fore the important and difficult problem of the effect of gaps on such things as lift, downwash at the tail, etc. These effects could be considered negligible on the older configurations with their high aspect ratios. However, they cannot be neglected as design progresses in the direction in which it is going, and some information on these important effects is badly needed. The authors of this paper deal with the problem from the theoretical approach, studying by use of linearized supersonic wing theory, the effects of gaps, Mach Number, and sweep on such things as spanwise lift distribution, total lift, center of pressure, drag due to lift, and vorticity at the trailing edge.

The effect of these gaps on tail interference was also investigated in an attempt to get some insight into their overall effect on the stability and trim characteristics of the aircraft. The results of this investigation were clearly presented in this paper and will be of unquestionably great interest to the design aerodynamicists who are searching for any data that may be available on this important subject.

The fourth paper, entitled "Supersonic Flow About Slender Bodies of Elliptic Cross Section," was written by A. Kahane and A. H. Solarski, from Republic Aviation Corporation's Aerodynamics Division. The authors stated at the outset that problems of supersonic flow past bodies of revolution at zero and higher angles of attack have been covered. Their theory was developed for slender bodies of elliptic cross section in supersonic flow and was based on the generalized cross-sectional slender body theory of Ward. Their theory was applied to the zero angle of attack pressure distribution on elliptic cones and parabolic arc bodies of elliptic cross section. They compared their results with the nonlinear elliptic cone calculations and experimental results of Ferri and found that the agreement was close. They also treated the wave drag of bodies with elliptic bases, and the wave drag coefficients for elliptic cones were calculated. Finally, they indicated a method for applying the method to bodies at angles of attack.

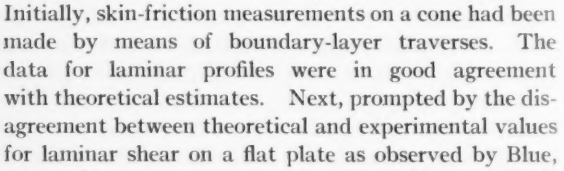
Aerodynamics—III

By
Francis H. Clauser
Chairman, Department of Aeronautics, The Johns Hopkins University

The third group of aerodynamics papers, coming during the evening of what had been an arduous day, was extremely well attended, and the audience was unexpectedly responsive in discussing critical points of the papers.

The first speaker was Franklin K. Moore, of the N.A.C.A.'s Lewis Flight Propulsion Laboratory. His topic was "Three-Dimensional Laminar Boundary-Layer Flow." He had first investigated the general properties of laminar boundary layers on slightly yawing cones at supersonic speeds. Next he had considered large angles of attack, at the same time restricting his analysis to the flow on the plane of symmetry. He stated that for a cone of given angle, as the angle of attack is increased, a point is reached for which no solution exists for the boundary layer on the leeward side according to his analysis. More strictly speaking, the boundary layer becomes infinite in thickness. Moore interpreted this as indicating that the boundary layers coming up around the sides of the cone form a wake that detaches itself at the top and moves out into the fluid.

The second paper, entitled "Experimental Investigation of the Characteristics of the Supersonic Laminar and Turbulent Boundary Layer at $M = 3.1$," by W. S. Bradfield, D. G. DeCoursin and C. B. Blumer of the University of Minnesota, was given by Mr. Bradfield. Initially, skin-friction measurements on a cone had been made by means of boundary-layer traverses. The data for laminar profiles were in good agreement with theoretical estimates. Next, prompted by the disagreement between theoretical and experimental values for laminar shear on a flat plate as observed by Blue, the authors set out to explore this field too. Their experiments also gave shearing coefficients that were too high. Believing this was caused by a premature thickening of the layer at the leading edge because of lack of sharpness of the edge, they prepared an edge with smaller radius and succeeded in reducing the discrepancy. They further showed that the discrepancies of their own work and those of others could be correlated by plotting against an appropriate leading-edge parameter. After the presentation, a lively discussion ensued, with members of the audience suggesting a variety of other explanations for the observed phenomena such as heat-conduction effects near the nose where the gradients are large.



Aerodynamics—III

The third paper, "Transonic Flow Past Simple Bodies" by J. D. Cole, G. E. Solomon and W. W. Willmarth, of the California Institute of Technology, was presented by Dr. Cole. Considerable progress has been made in recent years, by these authors and others, in obtaining solutions for the transonic flow around cones, wedges, and flat plates. In this paper, the greater emphasis was on the experimental confirmation of a portion of this theory and on the exploration of some of the interesting mixed flow fields that are present. The lift and drag results showed satisfactory agreement with theory. An interesting set of experiments was described in which the flow field on a cone is mapped out for the case where there is an embedded subsonic flow next to the cone itself. The field is not conical, but becomes conical as the Mach Number is raised, approaching the lower Taylor Maccoll solutions, which are conical.

The last paper, "Subsonic Compressibility Corrections for Propellers and Helicopter Rotors" given by E. V. Laitone, was written by Professor Laitone and Prof. Lawrence Talbot, both of the University of California at Berkeley.

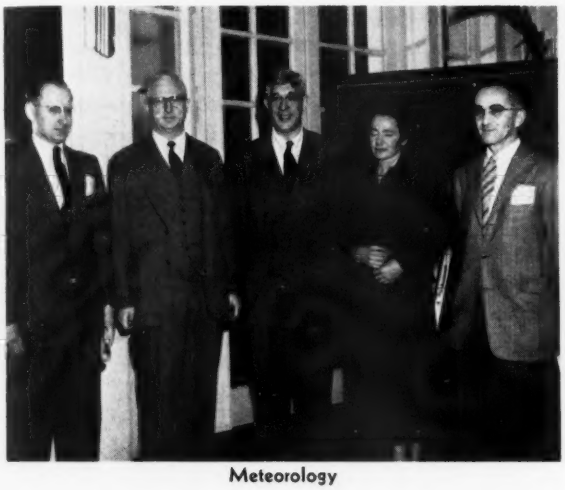
The authors, finding that propeller and helicopter theory had never had linearized compressibility theory applied to it, explored in detail the effect of the usual Prandtl-Glauert Mach Number corrections. Such simplifying assumptions as using a correction based on the rotational speed at the three-quarters radius were examined. These assumptions make practical analysis considerably simpler, and it is of benefit to know the limitations involved. Some older data for helicopter at high speed were shown to be in agreement with the analytical prediction.

All in all, the audience seemed to feel that, even though the day had been long and the papers many, it was worth the effort after all. To this the speakers said amen!

Meteorology

By
Horace R. Byers
Head, Department of Meteorology, University of Chicago

In a joint session of the I.A.S. and the American Meteorological Society, solar influences on the weather were examined, starting with disturbances in the atmosphere of the sun and working down into the substantial portions of the earth's atmosphere.



Meteorology

Dr. Donald H. Menzel, of Harvard College Observatory, in a paper entitled "Solar Variation and the Earth's Atmosphere" pointed out that in the visible portion of the spectrum the emission from the sun is essentially constant and it is in the far ultraviolet and soft X-rays where changes occur. There is a variation by a factor of two in the ionizing radiation between maxima and minima in the sun-spot cycle.

The corpuscular radiation is of special interest. In the aurora we see energy entering the atmosphere in the form of corpuscular radiation, which, while small in total energy, is so completely absorbed that it can be an important factor in the atmosphere. The corpuscular emission from the sun takes the form of clouds of corpuscles like spiral spokes of a wheel shot out to and beyond the earth's orbit. This material slides into the earth's atmosphere along the magnetic lines of force so that they are funneled in near the poles to form the auroras.

Dr. Joseph Kaplan, of the Department of Physics, University of California at Los Angeles, presented a paper prepared jointly with Mrs. Hilda Kallman entitled "Upper Atmosphere Reactions to Solar Activity." He told of his discovery in the laboratory of the "afterglow" spectrum of oxygen corresponding to the emission of light from the high atmosphere, such as seen in the light of the night sky or "airglow." The effects are present in the ultraviolet bands of 7,600 and 8,640 angstroms. If the ultraviolet radiation is increased by 20, the amount of atmospheric oxygen increases and shifts to lower levels in the atmosphere. Mrs. Kallman's work demonstrates that with a disturbed sun there is not only a greater electron density in the E layer but the maximum drops from a height of 108 to 96 km. An improved calculation was carried out by permitting both the molecular weight and the temperature to vary, a task not accomplished by previous investigators.

From 100 km. the discussion came down as low as 10 km. or less in the paper by Prof. Bernhard Haurwitz, Head of the Department of Meteorology and Oceanography at New York University. His contribution was entitled "Weather, Climate, and Solar Activity." He stated that, although the high atmosphere is the link between the sun and the lower atmosphere, the effects must be realized below the 100-km. level because only a millionth of the atmospheric mass is above that height. During solar flares the ultraviolet emission from the sun increases, causing the temperature to increase in the strongly ultraviolet-absorbing ozone layer. Since this layer is at about 30 km., there is still 1/100th of the atmosphere above it.

Some scattered observations of unusually marked increases in temperature in the ozonosphere were shown. One was a set of balloon observations last year in Berlin, which showed temperature increases at 30 km. of 25°C. or more in 2 or 3 days. This heating subsequently worked down to levels of 10 km. or lower. To get this heating by descending motion with adiabatic compression, the air would have to sink 4,000 m. This should increase the total ozone content of the atmosphere, and indeed on one occasion the ozone increased at the Arosa Observatory in Switzerland. In another case it did not. Dr. Haurwitz thought the temperature changes could not be explained easily by mechanical processes but hoped that the problem would be clarified soon by additional observations.

Electronics in Aviation—I

Impact of Electronic Trends on Aircraft Design

By

Gen. P. C. Sandretto

Assistant Technical Director, Federal Telecommunication Laboratories, Inc.

The Chairman introduced the session with the following remarks:

"While the Wright Brothers demonstrated powered flight in 1903, it was several years before the airplane had reached the stage of development where it could be regarded as a means of transportation and had acquired unique navigational problems. By one of those coincidences that have had a profound effect on the course

Electronics in Aviation—I

of history, radio development paralleled in time that of the airplane. It was in 1902 that John Stone obtained a patent on the first device applying radio to navigation, and in 1910, when the airplane was in need of navigation equipment, James McCurdy transmitted a radio message from the air. Radio and the aeronautical sciences were therefore united to bring forth air transportation.

"The joining of radio and aeronautics was, however, a union of convenience rather than love, because two more incompatible equipments than the airplane and the radio set could hardly be found.

"Flight's greatest obstacle is weight, and radio equipment is heavy. Radio equipment is delicate and dislikes a vibrating ambient. Yet all aircraft have pronounced vibration characteristics. Any protrusions reduce the efficiency of an airplane, yet all radio installations operate best with large protruding antennas. And so on, and on, we could mention the incongruity of applying radio to aviation.

"For years the problems of incompatibility were largely ignored. It was not until 1936 that the first aircraft had radio equipment engineered into it at the time of its inception. The radio engineers did very little better in approaching the problem from their end. This meeting today is to try to bring a better understanding between the aeronautical and the radio engineers of each others problems."

The first paper dealt with the systematic cooling of air-borne electronic equipment and was presented by Walter Robinson, who is Research Supervisor and Assistant Professor of Mechanical Engineering at The Ohio State University. After discussing the cooling problem, Mr. Robinson described seven methods that were applied to cooling a power supply unit having a heat dissipation of 330 watts. The following designs and methods were described:

(1) Open unit type 1: In this construction the airflow is produced horizontally across the tube surface.

(2) Open unit type 2: In this construction the airflow is produced vertically upward and essentially parallel to the tube surface.

(3) Closed conduction cooled unit: In this model the unit is closed and utilizes conduction principally to transfer heat from the components to a heat-exchanger plate.

(4) Sealed internally forced-air-cooled unit: In this design the vertical flow pattern of the open unit was used together with a heat exchanger having internal and external cooling passages.

(5) Mineral oil filled units.

(6) Freon filled unit.

(7) Spray cooled unit: This design overcame the weight disadvantage of the units in which all components were completely immersed. The system utilized a circulating pump and external heat exchanger.

The speaker made the statement that "comparison of the seven units here discussed cannot be generalized without exception. The relative merits are affected by the type of units for which the comparison is made."

In practical design, the cooling methods discussed are most likely to be used with equipments employing miniature- or subminiature-type tubes. The author conducted his tests on large tubes with noncylindrical shell. Various designing engineers are attempting to cool subminiature tubes through the use of springy tube shells that fit closely against the perfectly cylindrical surfaces of the tubes, and only a thin layer of silicone rubber is required to obtain perfect contact. It would appear, therefore, that it would be difficult to apply the speaker's work directly to many of the model designs; however, as a source of ideas for such design the paper was interesting. Some of the discussions that arose concerned the relation between the author's results and those for turbulent air cooling presented by an investigator in this field at last year's meeting. The author expressed the view that there were no differences between his work with air cooling and that of the previous year's author; however, the debate on this subject had to be terminated before a firm conclusion could be drawn.

The next paper was by William Sichak, J. J. Nail, and A. G. Kandoian, all of Federal Telecommunication Laboratories. Mr. Kandoian made the presentation. The paper was concerned with the pressing problem of obtaining satisfactory patterns from ultra-high-frequency antennas mounted on large aircraft. Mr. Kandoian stated that "a year ago at the same meeting Dr. John Granger, of Stamford Research University, in an excellent survey of the aircraft antenna problem, stated correctly that a solution to the ultra-high-frequency antenna problem was not in sight. It is our belief that in the past year this solution has actually come in sight, though it definitely is not here yet. Perhaps a year from now it can be said that a solution is at hand."

The speaker then went on to explain his reasons for believing that a solution was in sight. He discussed the extensive work that had been done over a period of time to determine the patterns that could be expected from antennas mounted in various places in the aircraft. The conclusion was reached that the solution must consist in the use of multiple antennas. It was stated that the problem of connecting multiple antennas to give suitable pattern was readily subject to solution when the equipment was to be used for distance-measuring or radar-beacon purposes but was not yet solved for other applications. The problems that must be solved in order to apply the multiple antenna system to other solutions were then discussed. The discussion of this paper was relatively short.

At last year's session increase in reliability of airborne equipment was discussed through the use of the transistor. Equally as important perhaps as the transistor is the magnetic amplifier, which can perform many

tasks for which electronic tubes have been used without the use of tubes. The next paper was by Henry F. McKenney entitled "What Magnetic Amplifiers Can Do to Increase Aircraft Reliability". The paper was presented by George F. Schroeder, Assistant Chief Engineer of the Ford Instrument Company. Mr. Schroeder stated that the advantages of the magnetic amplifier were (1) no warmup time and (2) no cooling problems.

In addition the speaker stated that the magnetic amplifiers had the following characteristics:

(a) Sensitivity: Amplifiers sensitive to less than 1 milliwatt have been devised.

(b) Gain: Power gains of a single-stage amplifier as high as 1 milliwatt have been obtained.

(c) Linearity: Constant output-input ratios up to 80 per cent of the output load have been obtained.

(d) Response time: Magnetic amplifiers can be made to fit the response time requirements for almost every application.

(e) Frequency response: Author showed a diagram of an amplifier with a phase lag of less than 40°.

(f) Circuit stability criteria: Author concluded that, by the use of bridge type circuits, he was able to reduce appreciably the effects of line voltage and frequency application.

After having discussed the design criteria the author went on to discuss magnetic amplifier applications to converters, turret drives, autopilot, and pulse generator. He stated that pulses with time durations of the order of 3 microsec. had been obtained. Considerable response followed Mr. Schroeder's discussion, and this concerned what had to be done to keep the performance of these magnetic amplifiers free from shock and also the question of maintaining high efficiency.

The last paper concerned the application of electronics to aircraft engine control. The paper by Joel D. Peterson and Robert W. Curran was presented by the latter, who is Project Engineer in the Automatic Controls Laboratory of the Eclipse-Pioneer Division of Bendix Aviation Corporation. Mr. Curran discussed the cumbersomeness of the present cable and pulley system of throttle and mixture controls and showed how the saving in weight could be obtained by the use of a servo-amplifier consisting of a 5-lb. servomotor and a 5-lb. servo-amplifier (per engine). The speaker then went on to explain the advantages in adopting the control to automatic mixing, etc. The speaker also discussed the difficulty that has been experienced in attempting to convince engine men that the equipment was reliable. He stated that only two tubes are used in the magnetic amplifiers and that in some 2,000 hours of operation there had been no failure. The discussion centered largely around the question of reliability and fail-safeness. Mr. Curran stated that the system was not completely fail-safe but that a number of provisions were made to take care of the most prominent failures that might occur.

Electronics Symposium

Edward Warner, Chairman
Council President, ICAO

NOTE: This entire symposium will be published in the May issue of the REVIEW.

Motorless Flight

By
Ben Shupack
Adelphi College

The Motorless Flight Session this year was devoted entirely to the problem of reducing drag and increasing lift by means of boundary-layer suction. The world's record-breaking sailplane, RJ-5, developed by R. H. Johnson at Mississippi State College to a glide ratio of 40 to 1 and a minimum drag coefficient of 0.01, illustrates the present maximum in aerodynamic refinement for pure geometric control of the boundary layer. Appreciable advances can only come from the extended control of the boundary layer permitted by the application of suction.

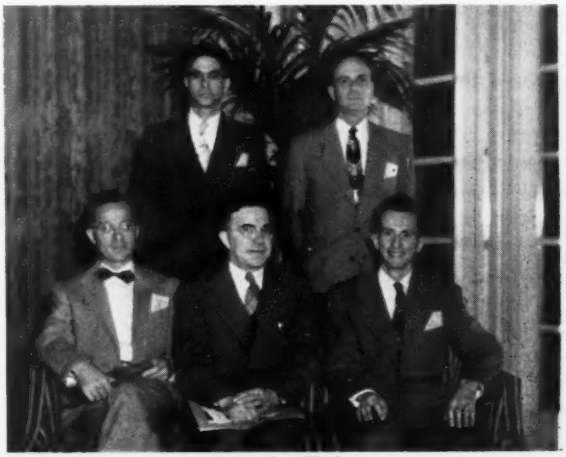
Some 49 years ago, Professor Prandtl announced the concept of the boundary layer and also the control of this layer through suction. Since then there have been many researches, particularly in Germany during the war, on suction boundary-layer control. Since the war there have appeared several additional investigations in this field among which the work of Pfenninger* is outstanding.

Last year, two papers appeared covering flight research on suction stabilized laminar boundary layers; Jones and Head† and Raspet.‡ The paper by Raspet

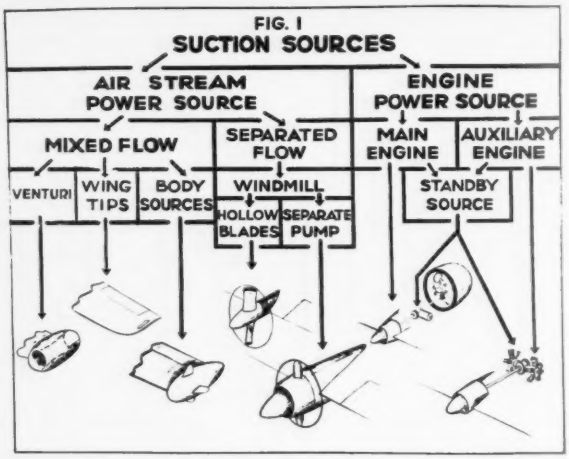
* Pfenninger, W., *Investigations of Reductions of Friction on Wings, In Particular by Means of Boundary Layer Suction*, N.A.C.A. T.M. No. 1181, August, 1947.

† Jones, M., and Head, M. R., *The Reduction of Drag by Distributed Suction*, Proceedings, Third Anglo-American Aeronautical Conference, Brighton, 1951.

‡ Raspet, A., *Boundary Layer Studies on a Sailplane*, Aeronautical Engineering Review, Vol. 2, No. 6, June, 1952.



Motorless Flight



was presented to the Motorless Flight Session just 1 year ago and showed that the boundary layer could be stabilized to a degree sufficient to remain laminar up to the trailing edge by suction applied through holes perforated into the fabric of the after portion of the airfoil.

This past year, a research team working under the direction of Dr. Raspet at Mississippi State College explored the possibilities of suction boundary-layer control much more exhaustively. The problems of suction sources, trailing-edge suction, suction through perforated surfaces and structural considerations as outlined at the joint I.A.S.-S.S.A. meeting in 1952 were elaborated on with the background of a year of study.

Since the foregoing problems are intimately interconnected in determining the final scheme of improved aerodynamic performance, they were presented together in a single session.

When the boundary layer remains laminar over the entire chord, the skin-friction drag and drag due to suction power are nearly equal. For this reason the problem of suction sources and flows merits as much consideration as does the problem of external aerodynamics.

Glenn D. Bryant, in his paper "Investigation of a Windmill Suction Source for Boundary-Layer Stabilization," made a broad exploration of suction sources for boundary-layer control. Fig. 1 illustrates the general survey. He discussed the mixed flow sources and showed that at present these are not promising, since their efficiency is extremely low—i.e., 4 per cent for a venturi. Bryant next chose to consider a windmill in which the suction air passed radially through the hollow blades and exhausted at the tips in the manner of a centrifugal pump. An experimental analysis of this windmill pump showed clearly that the next step in improved efficiency is a multistage axial blower driven by the windmill. This last unit is expected to have an efficiency of over 60 per cent.

It may be argued that a windmill has no place on a modern aircraft. Yet it is a device wholly independent of any power source, for it derives its power from the motion of the aircraft through the air. In any case, it is the solution of the moment and is ideal for application to the research aircraft that is a sailplane. Since no power source is available to the sailplane, it relies entirely on its stored potential energy—viz., altitude above ground. From this stored energy all losses must be paid for. If, then, a flight with suction boundary-layer control is compared with one without, one sees immediately whether there is a net gain in lift to drag ratio by using suction.

Bryant also discussed various engine-operated blower schemes. They enjoy the advantage in a powered aircraft of not requiring the inefficiency of the propulsion system to be added to the inefficiency of the suction system in determining the power cost of boundary-layer control.

Following Bryant's paper, R. F. Badertscher, of Battelle Memorial Institute, asked if the porous skin were used rather than just a trailing-edge slot to effect improved efficiency of the wing-tip suction method. The reply was that, because of the pressure characteristics of the tip suction source, it could not provide a sufficient negative pressure to prevent outflow in any but the rearward chordwise positions except at extremely high lift coefficients.

The next paper, "Flight Measurements of Automatic Trailing-Edge Suction on a Sailplane," was in essence a progress report by August Raspet on trailing-edge suction and showed little promise for automatic trailing-edge suction on sailplanes where an improvement in performance is the prime consideration. He was hopeful, however, that trailing-edge suction with a better suction source than the tip may provide a means for affecting control of aircraft by simply valving air. A. F. Kossar, of Kaman Aircraft Corporation, contributed the idea that negative damping in roll increment would result from the pressure variation of a tip source with lift coefficient. This is for a dropping wing, but for a rising wing with trailing-edge suction for lateral control the reverse condition applies. A suction source ducting air into the tip vortex was also suggested. This source has been studied by Raspet previously and was found lacking in pressure and in stability of the vortex.

Bruce H. Carmichael, in his paper "Flight Observations of Suction Stabilized Boundary Layers," gave a detailed study of suction through two surfaces of widely different porosities. A careful exploration of the region of stabilization of the laminar boundary layer on the same setup as used by Raspet showed that over-suction is a definite cause of destabilization. Reducing the porosity to about one-third in the same series of studies Carmichael found that the stabilization could be improved, and a laminar boundary layer maintained, over the full chord, at the higher air speeds where stabilization had previously failed. A Reynolds Number of 4,600 based on displacement thickness (believed to be the highest obtained to date in a suction stabilized boundary layer) was achieved on the low-porosity skin. In spite of the Pohlhausen parameter reaching minus 21, the laminar boundary layer did not separate. For nonsuction airflows, laminar separation

is predicted when the Pohlhausen parameter reaches a value of minus 12. A further revealing result of the research was the fact that the shape parameters of the velocity profile H, measured for the more efficient low suction case, remained around the Blasius value of 2.6 (Fig. 2), whereas the theoretical asymptotic suction required a value of 2.

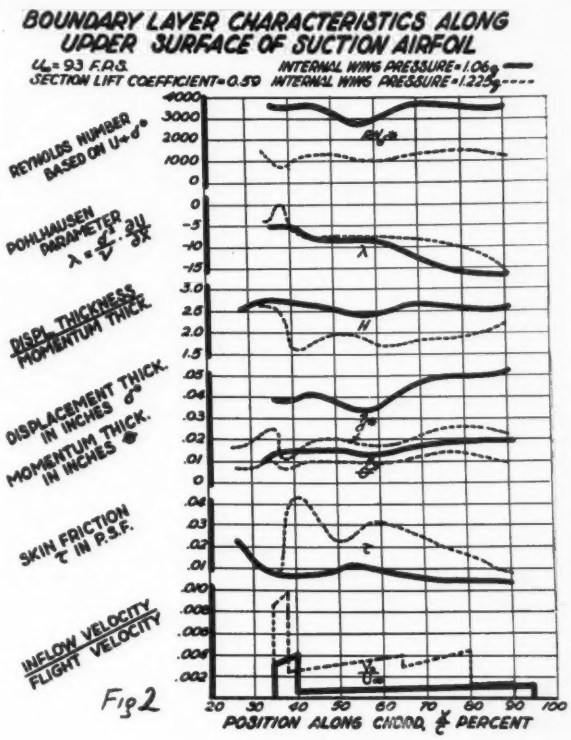
When the drag due to power required for suction was added to the external drag, there was measured a total effective profile drag coefficient only 54 per cent of that of the same airfoil in the smooth, impervious state. Carmichael pointed out that, although the overall drag reduction was promising, a minimum had not yet been reached. He had reason to believe that quantities of airflow considerably lower than required for asymptotic suction would suffice for stabilization. The applicability of these studies on a slow-flying sailplane to high-speed aircraft was stressed in the following manner: The former criterion for aerodynamic similitude—namely, the Reynolds Number based on chord and air speed—is valid only where the boundary layer is permitted to develop naturally on an impervious surface. Where the development of the shape and thickness is artificially controlled by properly distributed suction, the Reynolds Number based on potential velocity and momentum or displacement thickness is the sole criterion of similarity.

The discussion was initiated by William E. Buford, Supersonic Wind Tunnel, B.R.L., who reminded the forum that Dr. Hugh L. Dryden in his paper* showed that the effect of roughness was a function of the ratio of roughness height to displacement thickness. Dr. Dryden reasoned that, since suction in general decreases the displacement thickness, the effect of roughness becomes more pronounced when the suction is applied and thereby transition is encouraged.

Carmichael replied that, with properly distributed porosity, overthinning of the boundary layer is no longer an unavoidable consequence of increasing air speed. The flight data obtained to date demonstrate the desirability of permitting a gradual controlled growth of the boundary layer for reasons of flight economy, as well as for reasons of sensitivity to roughness. This departure from the concept of asymptotic suction is of marked significance to the field of boundary-layer stabilization.

W. Stepniewski, of Piasecki Helicopter Corporation, inquired whether a compartmented wing had been tried and elicited that such a wing was contemplated but had not yet been tested. Carlton Bioletti, of N.A.C.A. Ames, asked how an impervious low-drag airfoil would compare with the conventional suction airfoil at the same air speed and chord, to which Carmichael quoted for the low-drag airfoil a flight-tested coefficient of 0.0067 and for the suction airfoil 0.004.

* "Review of Published Data on the Effect of Roughness on Transition from Laminar to Turbulent Flow," presented at the Aerodynamics Session, Twenty-First Annual Meeting, I.A.S., New York, January 26–29, 1953.


BOUNDARY LAYER CHARACTERISTICS ALONG UPPER SURFACE OF SUCTION AIRFOIL
SECTION LIFT COEFFICIENT=0.59
INTERNAL WING PRESSURE=1.225
REYNOLDS NUMBER BASED ON
POHLHAUSEN PARAMETER
DISPL. THICKNESS MOMENTUM THICK.
DISPLACEMENT THICK. IN INCHES
MOMENTUM THICK. IN INCHES
SKIN FRICTION IN P.S.F.
INFLOW VELOCITY FLIGHT VELOCITY
POSITION ALONG CHORD, PERCENT
Fig 2

The final paper of this session, given by Charles B. Cliett, "Structural Comparison of Perforated Skin Surfaces with Other Means of Effecting Boundary-Layer Control by Suction," presented the results of a series of studies to determine the structural feasibility of perforated sheet materials that could be used in affecting boundary-layer control by suction.

Comparing the structural requirements for multiple slots as against porous surfaces shows that the perforated sheet materials are definitely superior, for the technique of using a perforated surface involves little additional structure over the conventional wing design. Empirical methods of predicting ultimate failure in tension and shear in perforated materials have been found which agree remarkably well with actual experiment. The research proves that the suction wing using a porous surface is aerodynamically advantageous and that the structural considerations have been sufficiently established so that such wings can be designed with confidence, see Fig. 4, page 42.

A. F. Kossar suggested that the fatigue picture might be improved by attention to the smoothness of the wall of the holes. A reduction in the presence of small cracks may improve the local fatigue characteristics. D. R. Jenkins, Battelle Memorial Institute, suggested the study of the variation in metallurgical transition temperature with numbers of holes and hole arrangement, since the proposed theory of strength is based on the ability of the materials to deform plastically. Professor George Madelung suggested that it might be worth considering elliptical holes.

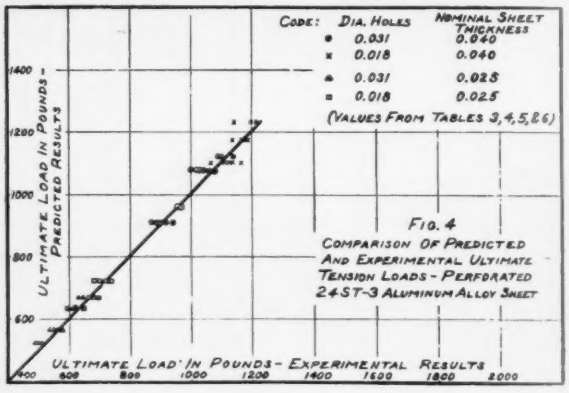


FIG. 4 COMPARISON OF PREDICTED AND EXPERIMENTAL ULTIMATE TENSION LOADS - PERFORATED 24ST-3 ALUMINUM ALLOY SHEET

This series of papers is concerned with an area of aeronautical research of high promise not only to the devotees of motorless flight but also to the powered-aircraft field. Possible performance improvements include a slower landing speed, a greater range, and a greater top speed. Such are the benefits that were forecast in the Motorless Flight Session of 1952 and brought nearer realization in this session of 1953.

Aviation Medicine

Aeromedical Problems of
Air Transport of This Next Decade

Brig. Gen. Otis O. Benson, Jr., U.S.A.F. (M.C.),
Chairman

Commandant, U.S.A.F. School of Aviation Medicine

NOTE: All papers presented at this session are published in the following pages of this issue of the REVIEW.

Air Transport—Safety

In Cooperation with The Daniel and Florence Guggenheim Aviation Safety Center at Cornell University

By
Jerome Lederer

Director, Flight Safety Foundation

[*At the request of the editors, Chairman "Jerry" Lederer has written up his introductory remarks, which made such an impression on the audience.*—ED.]

In his luncheon talk on Tuesday, January 27, Dr. C. C. Furnas referred to the excellent safety record of the domestic scheduled air lines as a freak point along a safety curve that seems to have leveled off. We hope this is not so, but it may well be. Only 1 year ago the industry was thrown for a tremendous loss by disasters at Newark and Idlewild. Neither the industry nor the public has recovered from that shock, in spite of the intervening safety record. Never have we witnessed so much interest and anxiety for safety on the part of the industry. They know that a safety statistic is like a Bikini bathing suit. What it reveals is important and interesting; what it conceals is vital!

Aviation Medicine

But when safety is discussed with engineers, one often hears that, if we need not go beyond a certain safety point, one fatality per 100 million is often mentioned as satisfactory. Unfortunately, the public does not think in terms of statistics. It thinks in terms of disagreeable personal consequences.

If you were ordinary people instead of engineers, I could prove this to you with a rifle. The rifle is an airplane; you are the public. I am the pilot. I don't know whether this rifle is loaded any more than a pilot knows what internal troubles are impending in his plane. So when I point the rifle at you, as I will, you may be under no hazard whatever if it is not loaded. Anyway in a room as large as this, which holds about 500 people, your chance of being hit is one in 500. I shall put the safety catch on and, since it has no electrical circuits or radio tubes, its probability of malfunctioning is relatively low. I am reasonably familiar with guns. So when I point this rifle at you, the chances of your being hit by a bullet are statistically small—probably much less than being involved in an airplane accident. Therefore, when I point this rifle at you, you as engineers, realizing how safe this is from

Jerome Lederer

the statistical standpoint, will have no emotional reaction.

But if you were the public, you undoubtedly would be a wee bit worried.

Anxiety never disappears in a human being in an airplane—it merely remains dormant when there is no cause to arouse it. Our challenge is to keep it forever dormant.

Public opinion, the human reaction to air transport, is an intangible force, but no engineer engaged in airplane design can afford to ignore its strength or its direction.

Air Transport—Safety

Two of the papers presented during this Air Safety Session were concerned with propeller reversal problems, and one dealt with problems encountered by the pilot in the last 3 min. of flight under instrument conditions.

The first paper, by David Posner, C.A.A., was an excellent résumé of the present status of the proposed fixes to prevent inadvertent propeller reversal. Mr. Posner began by recalling the importance of reversing propellers to safety and stated that there were 38 accidents in the period 1947 to August, 1952, which might have been prevented. These accidents resulted in 90 fatalities and 26 major injuries. Against this, there have been two fatal accidents attributable to an inadvertent flight reversal. A careful analysis of the crash in which the unwanted reversals occurred points to the following: (1) electrical faults in the propeller control and (2) inadvertent movement of the throttle into reverse in flight. Posner called attention to stray electrical currents, faulty electrical connections, and deterioration of insulation as the main troubles.

After discussing the various ways in which the throttle can contribute to an advertent reversal, he dealt with proposed "fixes." One fix calls for a required "lift" of the throttles to reverse the propellers and another requires auxiliary levers that the pilot must operate before the propellers can be reversed.

The second paper, by Mel Gough, Directorate of Flight Test Research at the N.A.C.A., Langley Aeronautical Laboratory, described a simple device to warn a pilot of the imminence of change of propeller thrust. This device consists simply of a pressure tube (pitot tube without the static openings) installed behind each propeller. Two tubes are installed, one on top and one on the bottom of the nacelle. The pressure in each pair of tubes is averaged out before being shown as a single reading on the indicator in the cockpit. This gives the pilot a positive indication in the cockpit as to the relative thrust of each engine. If a propeller should begin to reverse inadvertently, he would get an immediate clue from the dials.

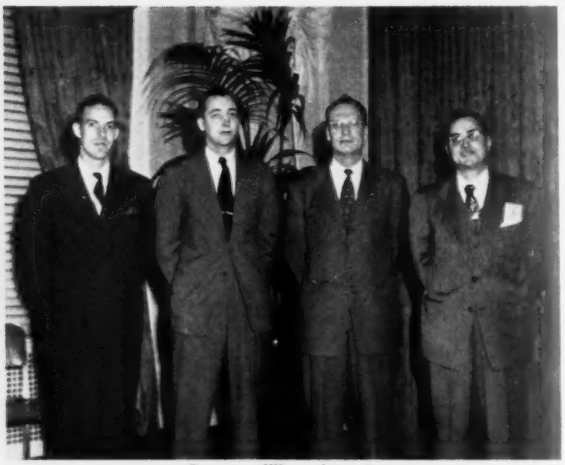
In the ensuing discussion the point was made that this would be adding another instrument to the already crowded instrument panel. Gough responded by showing how this indicator is in the form of a "totalizer" and could replace several other instruments in the cockpit such as manifold pressure, tachometer, etc. He also stressed the point that it would quickly indicate any tendency to yaw on take-off even before the pilot could sense it in his controls.

Captain Arthur Jenks, Chief, Flight Inspection Division, Federal Airways, C.A.A., described the problems that face a pilot in the last 3 min. of an instrument flight. He emphasized that adherence to a predetermined straight-line path is an extremely difficult flight maneuver, especially under instrument flight conditions. His motion pictures showed how aircraft tend to slide sideways rather than take up a new course when the controls are moved to correct for small variations from a desired path. The airplane follows a ballistic path rather than an aerodynamic path, and the inability of the pilot to recognize this turn/time lag induces overcorrection and the development of an oscillatory flight path. He stressed the need for further attention to this critical problem.

Rotating Wing Aircraft

By
Thomas J. Harriman
Assistant Chief Engineer, Helicopter Division, Bell Aircraft Corporation

The combined A.H.S.-I.A.S. Helicopter Session at the Annual Meeting of the Institute of the Aeronautical Sciences in New York saw three papers presented to approximately 150 people. The first was given by Charles W. Ellis, III, Test and Development Engineer at Kaman Aircraft Corporation, entitled "Effects of Articulated Rotor Dynamics on Helicopter Automatic Control System Requirements." In order to provide helicopter automatic control designers with a better understanding of some of the limitations and requirements imposed on any stabilization or control device by the conventional type of articulated lifting rotor, a theoretical investigation was carried out to determine the influence of such a rotor on the dynamic properties of a stabilized helicopter. This investigation indicated that any analysis of a high-gain attitude stabilization



Rotating Wing Aircraft

scheme should include the dynamics of the rotor; it also indicated that simplified methods of considering the effects of such rotor dynamics were feasible. In conjunction with this theoretical investigation, an experimental program was carried out. Comparison of theoretically predicted and experimentally measured helicopter dynamics indicated the validity of the simplified methods considered and bore out the conclusion that rotor dynamics should be included in high-gain attitude stabilization analyses. Ed Carter, of Sikorsky, pointed out in the discussion and question period that the variation between pitch and roll inertia ratios probably requires a significant difference between pitch and roll feedback ratios. Mr. Sissingh, of McDonnell, mentioned the importance of blade inertia value; it was reported that $\gamma = 10$ was the value used.

The second paper was "Forward-Flight Lateral Stability and Flying Qualities Studies of the Tandem Helicopter," by Kenneth B. Amer, Flight Research Division, N.A.C.A., Langley Field, Va. Results of flight-test measurements and corresponding pilots' opinions of the forward-flight lateral-directional flying qualities of a tandem helicopter in several different configurations are compared and analyzed. The conclusions are presented in the form of desirable flying qualities goals applicable to all types of helicopters. Comparison between theoretical analyses and experimental results indicates theory to be a useful tool for studying means to achieve these goals. Possible practical methods to meet these goals in the tandem helicopter are suggested, based on results of theoretical analyses. Mr. Amer's paper was an excellent combination of applied theory and practical testing of a full-scale helicopter. The physical explanations for the important stability parameters were directly shown by slides of the appropriate diagrams. Undoubtedly this work will be standard text material in lateral-directional stability for some time. From the pilots' and engineers' evaluations of the tests, it was concluded that helicopters should have directional stability with pedals fixed in all flight conditions. There should exist no Dutch roll and there should be no rolling velocity reversals. The important stability derivatives are effective dihedral, which should be reduced to a low value; damping in roll, which should be large; and roll due to yawing, which should be large and positive. In the discussions, Mr. Kossar, of Kaman, indicated a directional stability complication because of relative angularity of the rotor axes. Mr. Adler, of Piasecki, illustrated that a tandem helicopter depends more on the fuselage for its directional stability, while the synchropter designer must pay close attention to rotor axis angles. In response to the Chairman's question concerning damping of roll sometimes becoming negative, Mr. Amer explained that speeds during the subject flight testing were too low to change the sign of the damping moment.

The last paper was scheduled to have been *Maneuvering Loads and Effect of Rapid Control Movement*, by William Wettengel, Flight Test Engineer, Helicopter Division, Bell Aircraft Corporation. Because clearance was not received for this presentation, Paul Kesling, also of the Flight Test Engineering Section of Bell, gave an interesting technical description of the record-breaking long-distance hop of a Bell Model 47 helicopter, illustrated by photographs of the special equipment and Mr. Kesling's amusing revelations. The paper contributed a great deal to the interest and informativeness of the meeting. The difficulties of proper weather were discussed along with the pilot's problem in contending with a smoky radio. While leg fatigue became a serious comfort problem, the pilot's condition was adequate for precise control throughout the flight. Twelve hundred and seventeen miles in 13 hours were the vital statistics of the record.

Plan Now to Attend

Fourth International Aeronautical Conference

I.A.S.-R.Ae.S., London, England, September 7–17, 1953

TRENDS AND TRANSITION IN AEROMEDICAL PROBLEMS

With A View Toward The Next Ten Years

Brig. Gen. Otis O. Benson, Jr., U.S.A.F. (M.C.)*

U.S.A.F. School of Aviation Medicine

Introduction

The title of the aeromedical symposium presented before the Institute of the Aeronautical Sciences was "Aeromedical Problems of Air Transport of This Next Decade." In planning the symposium and in the papers published herein, we have not adhered rigidly to the title but, rather, we have attempted to present the human problems of manned flight as they exist today and as they are foreseen in the ensuing decade. A dichotomy of exposition occurs because the aeromedical problems of civil air transport represent one group of stress situations, while the most advanced experimental and military flying create environmental exposures quite different in degree or in character. The reasons are obvious when one recalls that the basic tenets of commercial aviation are safety and economy, while maximum performance and world leadership are a national objective for the military. Thus, commercial aviation progresses some 5 to 10 years behind the most advanced military aviation accomplishments, and to a great extent the aeromedical problems of civil aviation today are those the Air Force encountered toward the conclusion of World War II. For the purposes of our discussion today, then, we have set as the parameters the aircraft performance data shown in Fig. 1.

It is not our intent to enter into the popular international pastime of speculating on future aircraft performances, but it would seem that there is abundant evidence indicating that, if anything, we err on the conservative side. It is of historical interest to review the aircraft performance records of the period 1905 to 1950 and to note the trend since 1947 (see Fig. 2). Only recently was it announced that an operational-type jet fighter flew at 699.9 m.p.h. and that a service-type bomber flew from Honolulu to San Francisco in about $4^1/_2$ hours. This latter achievement makes us realize how truly small the world is becoming in terms of hours of travel between places we formerly considered distant (see Fig. 3). At 500 m.p.h., jet-bomber or jet-transport speed, the earth can be circumnavigated at the equator in about 2 days of continuous flight—around the North Temperate Zone it can be done in less time.

Presented at the Aviation Medicine Session, Twenty-First Annual Meeting, I.A.S., New York, January 26–29, 1953.

* Commandant.

Aeromedical Problems of Today

The most important aeromedical problems of today are occasioned by pilot error (erring pilot), loss of cabin pressure, and escape from highest performance aircraft. Pilot error remains the single most important cause of aircraft accidents and mission failure. Great energy and much substance are going into studies to try to define the problem in all of its ramifications and to

AIRCRAFT PERFORMANCE AFFECTING AVIATION MEDICINE
1953 — 1963

SPEED

CIVIL AIR TRANSPORT —— JUST SUBSONIC
MILITARY AIRCRAFT —— TO 2,000 M.P.H.

ALTITUDE

CIVIL AIR TRANSPORT
ACTUAL ALTITUDE —— NOT OVER 50,000 FT.
CABIN ALTITUDE —— NOT OVER 10,000 FT.

MILITARY AIRCRAFT
ACTUAL ALTITUDE ———— 100,000 FT.
CABIN ALTITUDE —— NOT OVER 37,000 FT.

Fig. 1.

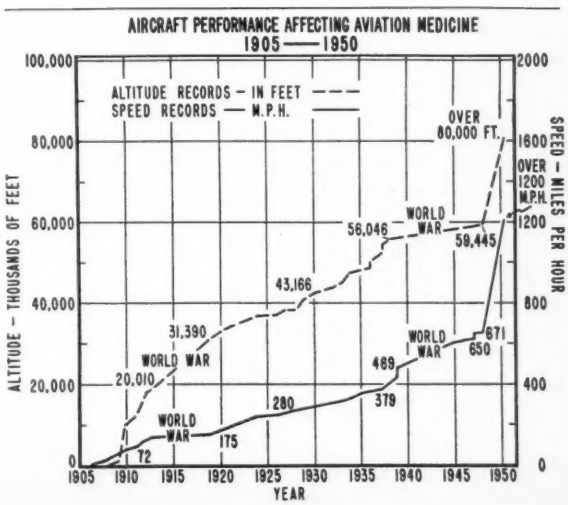


Fig. 2.

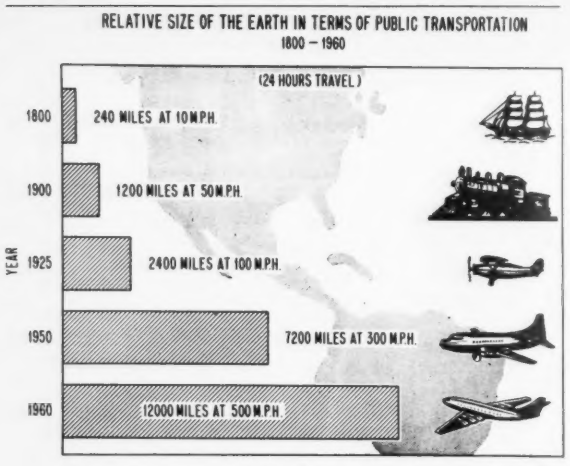


FIG. 3.

obtain additional solutions. No one yet has disproved the old adage: "To err is human." Continued effort is going into both psychological and physical selection research. Further culling or selection is performed by the air lines in employing former military pilots, and in certain military programs there is an element of super-selection of air-crew personnel. At best, refinements of minor degree have been obtained to date. The problem of the "aging pilot" is receiving increased emphasis, but important criteria are not yet elaborated. Improvement in cockpit layout, work space, and instrument design has been studied, and greater standardardization has been advocated, together with a better display of flight- and engine-instrument information. It seems to the writer that advancements in this latter endeavor have been all too retarded. A current study of "near-accidents" may bring forth new data from which practical applications may stem.

Failure of cabin pressurization is, in general, an indictment of the engineers. Aside from battle damage in military aircraft, it should not occur. In most recorded instances it has been due to loss of an astrodome or hatch—a structural failure. Something as simple as a coarse nylon mesh over hatches and other large orifices would have prevented loss of life and may yet be advocated as lifesaving. The sudden loss of cabin pressurization where the ambient pressure is considerably less than the cabin pressure produces the following untoward events, in order of occurrence: decompression, expulsive effect about the orifice, hypoxia (acute oxygen deprivation), and dysbarism ("bends" or related symptoms). The danger to occupants of an aircraft suddenly decompressed is caused by the almost instantaneous expansion of the body gases. The lungs have the most delicate structure, and laceration of the lung tissue with massive air embolism has been observed following explosive decompression where the time of decompression was extremely rapid and the pressure differential great. This has occurred in mishaps in experimental diving and is more a potentiality than an actuality in aviation experience at this writing. This consideration should not be overemphasized, but as flight goes to greater heights it should not be minimized either. Experimental studies completed at the end of World War II defined the upper limits of man's tolerance to explosive decompression. Dr. Luft discusses this in somewhat more detail in his paper on page 56.

The expulsive effect of the air escaping from the aircraft cabin through the orifice—whether it be astrodome, hatch, or hole produced by a missile—is a force of some magnitude. Data have been calculated, based on cabin volume, size of orifice, and pressure differential, to show the length of time taken for the decompression and the force of the air stream. For the purposes of this discussion it suffices to relate that there are now a number of protocols of persons literally blown out of the aircraft when a hatch, an astrodome, or an observation window fails in both pressurized bombers and civil air transports. In every instance reported to this writer, the cause of the mishap has been attributed to structural failure and nonuse of a restraining belt by the person lost.

The seriousness of the hypoxia following loss of cabin pressurization is, to any practical extent, dependent upon the altitude at which the mishap occurs. There is one solution, and one alone, and that is the rapid administration of oxygen to crew and passengers. The time of useful consciousness following decompression is shown in Fig. 4.

For most practical considerations, these data also apply when oxygen is interrupted during flight at the ambient pressure. The time of useful consciousness under conditions of low oxygen pressure is thought to be so important that both Colonel Campbell (see page 50) and Dr. Luft discuss it in their papers. Of further interest is the fact that the pilot of the Comet I wears his

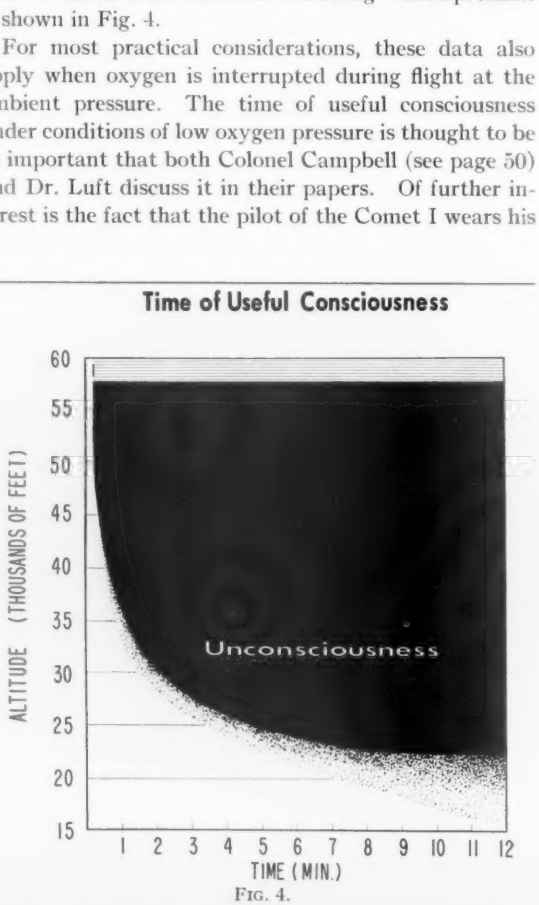


FIG. 4.

oxygen mask, although breathing air, during routine flights. One quick adjustment of the oxygen regulator produces 100 percent oxygen.

The question of dysbarism (bends or related symptoms) is not an important one in civil aviation at this time. Theoretically, decompression symptoms, such as "bends" and "chokes," could occur at $^1/_2$ atmosphere (18,000 ft.), but in actual practice relatively few people evidence symptoms below 30,000 ft., even after exposures of some duration. The likelihood of clinical evidences of dysbarism significantly increases as altitudes over 30,000 ft. are attained, and the exposure time need not be prolonged. Exercise greatly enhances the probability of acquiring symptoms at the higher altitudes (e.g., 40,000 ft). It is unlikely that commercial aircraft would remain at the higher altitudes upon loss of cabin pressurization, and only in war situations might military aircraft not want to descend. The time is coming, however, when descent to lower altitude might be critical, and that is the situation in transoceanic jet operations where there is loss of cabin pressure midway over the ocean. The fuel supply may very well call for the most delicate of compromises to safeguard the passengers yet permit flight at an altitude where fuel consumption is not disastrous.

The problem of escape from a disabled aircraft at high speed and high altitude is distinctly a military problem but nonetheless acute. The ejection seat has been installed in most of the current jet aircraft, although there are a few exceptions. In the latter, escape is almost impossible at high speed. Even with the ejection seat, there are problems of rotation of the seat during descent and the pilot's separation from it in the case of low-altitude bailout. In the ejection seats now employed, the pilot frees himself from the seat by opening his safety harness after he is ejected. He must then open his parachute, but he is instructed to release himself from his seat as soon as possible and delay opening his parachute as long as possible to prevent fouling with the empty seat. Developments for some time now have been directed toward completely automatic operation after the pilot has triggered his ejection seat. The mechanisms are designed to open automatically at 20,000 ft. the lap belt that holds the pilot to the ejected seat, or in 3 sec. if below that altitude. When separation has occurred, a static line from seat to parachute pulls the ripcord. This development is needed now in proved form. The physiological data are now available for downward ejection, and it has been concluded that human tolerance to negative *g* of short duration is in the range of 10–30*g*, lasting approximately 0.1 to 0.2 sec. This tolerance makes downward ejection feasible in certain type aircraft operating at subsonic speed and may well be the answer for certain jet bombers.

The Problems of Jet-Transport Flight

The problems of jet-transport operation are focused on flight at 40,000–50,000 ft. more than on any consideration of speed in the range of 450–550 m.p.h.

In discussing the question of speed, first, it should be apparent that pilot error becomes more crucial and probably more disastrous. Colonel Byrnes, in his paper on page 61, presents the reaction time in the visual processes that illustrate the increasing significance of human reaction time. The short or overshot landing under marginal weather conditions is serious in jet operation, as is the failure to recognize every contingency that affects fuel consumption and fuel supply.

In the still experimental flights of the jet transport, Comet I, there has been no passenger comment on increased *g* effects. This means that care is exercised to increase the radii of turns or to make turns at the lower feasible throttle settings. It is of interest to note that at 500 m.p.h., using a standard 3 deg. per sec. turn, an aircraft would be subjected to 1.56*g* and the radius of turn would be 2.65 miles. In passenger transportation at jet speeds, turns cannot exceed $1^1/_2$ deg. per sec., and the radius of turn will be correspondingly lengthened to avoid passenger discomfort.

In flight at 40,000–50,000 ft., where jet transports must operate in the interest of fuel economy, the principal problem is that of explosive decompression and failure of cabin pressure. It is probable that the large cabin volume of jet transports in relation to the size of the orifice that might fail inherently will give protection to the aircraft occupants in terms of a more tolerable decompression. In other words, the time of decompression will be prolonged. However, although the crew and passengers have avoided damage to their lungs and hollow organs, they are confronted with an acute oxygen deficiency. Reference is again made to Fig. 4, showing the time of useful consciousness at 40,000 or at 50,000 ft. At the lower of these two altitudes, a person has about 30 sec. to obtain a source of oxygen; at 50,000 ft., he has about 15–20 sec. Obviously this does not allow much time to search for an oxygen mask, make connections to an O_2 regulator, and adjust the regulator. It has previously been stated that the pilot of the Comet I wears his oxygen mask in flight, and the other crew members have theirs partially *in situ* for flights in the vicinity of 37,500 ft. The obvious answer for civil airline operation is a short briefing of the passengers on oxygen equipment ready for use, the crews to be as ready as the Comet I crew is currently. Rapid descent to lower altitudes will be required to prevent dysbaric symptoms in passengers and crew. Descent to altitudes below 10,000 ft. will probably be necessary to institute resuscitation procedures on some of the passengers who failed to obtain their oxygen equipment rapidly enough.

The Aeromedical Problems of the Most Advanced Flying of This Decade

In discussing the human element in the operation of aircraft at great speed and at altitudes of 80,000–100,000 ft., we are prone merely to consider the physiological limitations of man and start engineering design from this parameter. It would seem far more important and

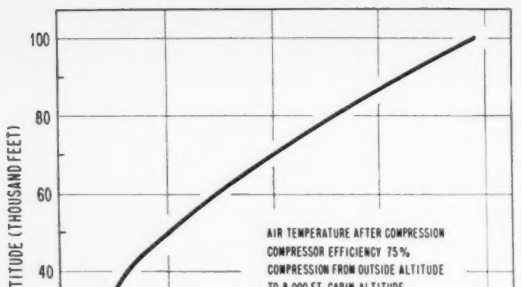


FIG. 5.

G-FORCES ACTING UPON MAN AND AIRCRAFT FLYING IN A STANDARD 3°/SEC. TURN AT VARIOUS SPEEDS (TIME REQUIRED FOR FULL TURN 120 SECONDS)

SPEED M. P. H.	RADIUS STATUTE MILES	G
100	0.53	1.03
300	1.59	1.23
500	2.65	1.56
700	3.71	1.95
900	4.77	2.48
1,000	5.31	2.59
1,500	7.96	3.72
2,000	10.61	4.88

FIG. 6.

G-FORCES ACTING UPON MAN AND AIRCRAFT FLYING IN TURNS OF VARIOUS RADII AT VARIOUS SPEEDS.

SPEED MPH.	RADIUS STATUTE MILES 0.5	1.0	2.0	5.0	10.0
100	1.03 (113)	1.01 (226)	1.00 (452)	1.00 (1131)	1.00 (2262)
300	2.49 (38)	1.52 (75)	1.15 (151)	1.03 (377)	1.01 (754)
500	6.41 (23)	3.32 (45)	1.87 (90)	1.18 (225)	1.05 (452)
700	12.50 (16)	6.28 (32)	3.26 (64)	1.60 (161)	1.18 (323)
900	20.60 (13)	10.28 (25)	5.24 (50)	2.28 (126)	1.43 (251)
1,000	25.35 (11)	12.70 (23)	6.41 (46)	2.72 (113)	1.61 (226)
1,500	57.00 (7)	28.55 (15)	14.30 (30)	5.80 (75)	3.02 (151)
2,000	101.30 (6)	50.70 (11)	25.40 (23)	10.20 (57)	5.16 (113)

FIGURES IN BRACKETS INDICATE THE TIME IN SECONDS REQUIRED FOR A 360° TURN.

FIG. 7.

appropriate to design the aircraft and equipment to permit "full faculty" performance by the air crew and not impose limitations or accept marginal human performance. Unfortunately, there are no data on man which systematically define and describe the additive effects of superimposed stresses in the combinations of their occurrence. Some information is available on the effect of heat on *g* forces, and much has been written in a general way on fatigue as an additive factor without depiction of clearly defined decrements in performance of one type or another. Closely related data on human performance under conditions of multiple environmental stresses are needed.

It is now obvious that flight at altitudes in excess of 80,000 ft. must be performed in sealed-cabin aircraft. Some data on air temperature after compression of air at varying altitudes are shown in Fig. 5. These data are well known to engineers, but to those of us without this type of professional knowledge it becomes apparent that the pressure cabin ceases to be feasible for truly high-altitude aircraft. The toxicity of ozone, found in increasing concentrations above 80,000 ft., is also a consideration at this time in favor of the sealed cabin. Since the sealed cabin represents a closed ecological system, there is no relation between inside and outside air, and only temperature and radiation will penetrate the cabin walls. The respiratory and other physiological requirements must be supplied and controlled from within the cabin. The sealed balloon gondola of the Piccard brothers and of Stevens and Anderson represents the prototype of this aircraft cabin. Extensive study and refinements in equipment are needed to determine the balance of respiratory gases, water vapor, and temperature in a closed ecological system. The method of maintaining cabin pressure should be studied extensively to obtain an optimum solution. The sealed cabin of the X-S1 used compressed nitrogen gas to maintain the cabin pressure, which dictated the continuous use of an oxygen mask by the pilot. In all, the sealed cabin presents no completely novel human problems, but an extension of our current knowledge is required.

The hazard (and the word is *hazard*) of explosive decompression at extremely high altitudes is great indeed. Even following the explosive character of the decompression, the onset of unconsciousness in about 15 sec. due to acute oxygen want dictates that a standby emergency pressure suit be worn and that its pressurization be automatic and almost instantaneous. The U.S. Air Force has developed such a partial pressure suit with automatic inflation. This suit is essentially a tight fitting coverall, with a full head helmet and mask, which applies pressure through longitudinal capstans that inflate. Good mobility is obtained in both the non- and fully inflated state. At best, however, this suit is a lifesaving equipment and could not well be tolerated for prolonged wear at high altitude. As an additional consideration, it does not give significant protection from dysbarism over any period of time.

The "heat barrier" is a new term in aeronautical language, and it might appear that this is a more formidable phenomenon than the sound barrier. Pilots of high-speed test aircraft have reported "hot" cockpits during speed runs. The solutions to the problem of aerodynamic heating are: (1) mechanical cooling of the cabin and (2) provision of personal thermal pro-

tection by means of air-conditioned clothing. This latter process may be required to ensure complete pilot protection as a standby measure. Air-cooled suits have been laboratory-tested and prototype items developed. The means of permitting higher aircraft skin temperatures to develop and the functioning of much ancillary equipment at the high temperatures I leave to the engineers.

The *g* forces acting upon man and aircraft flying in a standard 3 deg. per sec. turn at varying speeds are shown in Fig. 6. It is to be noted that at 1,000 m.p.h. the radius of turn is 5.3 miles, while the pilot is subjected to 2.6*g*. This is well within his tolerance, but at 2,000 m.p.h. the same turn (3 deg. per sec.) puts the pilot at about the average blackout threshold throughout the entire turn. In Fig. 7, the very high *g* forces imposed on a pilot and aircraft flying at high speed in turns of short radii are shown. The use of the prone position for pilots has been studied but has not received favorable consideration by designers and military planners. The anti-*g* suit has been found to be acceptable but gives limited additional protection (1.5*g*).

Escape from supersonic aircraft is considered to be impossible without ejection, and it is agreed that full body protection from air blast must be given. The ejection "capsule" is much discussed in aeromedical and aeronautical groups, who believe it to be the ultimate answer to the problem of emergency escape at speeds over Mach 1. There are no important factual data published pertaining to the use of this device. Human tolerance to rotational or spin forces about axes through the body must be determined prior to use of the ejection capsule, and it is conjectured that initial stabilization of the ejected capsule will be most difficult to attain. The location and force of the explosive charges required to free the capsule from the air frame, the energy needed for adequate ejection, and the descent characteristics of the capsule are of concern to aeromedical investigators. Some experimental progress is being made, but questions are more numerous than answers at this time.

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Atmospheric Characteristics of Greatest Human Significance in Aviation of the Next Decade

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Introduction

For purposes of this discussion, an arbitrary prediction has been tendered that, during the next decade, civil passenger travel will be feasible up to altitudes of 50,000 ft. and that military flights to 100,000 ft. will be possible. A second parameter of maximum speed—just under the velocity of sound for civil travel and 2,000 m.p.h. for military travel—was also tendered. It is the purpose of this presentation to discuss the atmospheric phenomena that will be encountered in such flights in relation to their biological implications.

Knowledge of atmospheric characteristics has increased rapidly during the past few years, largely through the application of new physical instruments, sounding balloons, and rockets; the intertwining of many disciplines; and, above all, the mass effort of a large number of able scientists.

Similarly, knowledge of biological stresses produced by environmental changes occurring as a function of altitude and speed has increased through advancement of the science of aviation medicine. This advancement is again the result of mass effort, new instrumentation, and the intertwining of many disciplines in a large number of laboratories spread over most of the world.

Discussion

The classic concept of the atmosphere is shown in Fig. 1. It is, of course, now well known that the situation is not so simple and well defined; however, its consideration will afford a background for study of some of the most important variations. In Fig. 1, the transport and military aircraft are placed at their respective altitude ceilings. It should be noted that civil transport operating at a ceiling of 50,000 ft. is in an ambient atmosphere of about 88 mm. of Hg or a little less than one-ninth the pressure at sea level; consequently, it is pressurized to about 10 lbs. per sq. in., thus attaining an equivalent cabin altitude of 8,000 ft. with a little to spare for leaks, etc.

The military aircraft shown at the ceiling of 100,000 ft. is rocket-propelled. Its cabin is a sealed cabin. It is operating in an ambient atmospheric pressure of 8 mm. of Hg or less than 1/95 of 1 atmosphere of pressure. At this level almost 99 per cent of the bulk of the atmosphere lies beneath the craft. More will be said about the sealed cabin later.

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Troposphere

Let us turn first to the troposphere, (Fig. 2.) The importance of the troposphere lies in the fact that each and every aircraft must operate within it at some portion of the flight operation. Aircraft must at least ascend and descend through it. Within the troposphere lies more than 75 per cent of the atmospheric bulk and almost all of the weather. Its ceiling is the tropopause, which at times is poorly defined. Its upper contours may occur in waves and folds. The position of the tropopause varies with season and with latitude, as well as weather conditions and time of day.

The visual barriers to flight occur within the troposphere as a result of its water vapor and aerosols. Clouds, fog, haze, rain, and their frozen counterparts present a visual hazard when aircraft operate within them. Weather build-ups, even to altitudes of 55,000 ft., with their associated turbulence and icing can be encountered in the tropics. The atmospheric aerosols or particles of dust, carbon, sand, and salt also produce visual hazards in the lower regions of the tropopause but at times are encountered at moderate levels.

Associated with the tropopause are the jet streams meandering around the globelike rivers, splitting and at times again merging, twining, and ebbing, with speeds varying from 60 to more than 300 m.p.h. The latitude at which they are encountered and their intensity, size, and shape vary with the season and, to some extent, longitude by longitude. In some areas, especially over high mountains, they may slow to a speed that renders them unrecognizable. The streams are not limited to a particular level but extend vertically with their core located at, or just beneath, the tropopause. In the Northern Hemisphere the core appears to range from the region of latitude 30° in the winter to latitude 55° in the summer. Certainly the jet streams will be used more and more for their boost effect as their positions and characteristics become more and more predictable.

Any factor, such as a jet stream, which increases speed from point to point or lengthens travel potential through decreased fuel consumption per mile traversed may have biological, as well as commercial, implication since it allows the peoples of the earth to mix more freely and thus disseminate diseases within their incubation periods—the period before recognizable symptoms appear.

Most of the known turbulence of the atmosphere is found within the troposphere, usually in the lower levels. Severe turbulence associated with jet streams,

however, has been reported, although definite correlation with the jet streams is still not completely confirmed.

The biological stress, hypoxia, resulting from lowered partial pressure of oxygen, which in turn is a function of decreased barometric pressure, has been the stress most extensively studied in the researches of aviation medicine.

The percentage of oxygen in atmospheric air remains at a level of approximately 21 per cent through the entire altitude zone of consideration. However, at about 10,000 ft., barometric pressure is reduced to approximately 522 mm. of Hg. As a consequence, there is a lowering of the oxygen pressure in the alveolar air to approximately 60 mm. and in the blood to a saturation of approximately 90 per cent. As about 96 per cent saturation is the normal average, little in the way of symptoms is produced even at this level. However, this is considered to be the upper limit at which breathing of ambient air alone is not deleterious so long as night visual efficiency is not a criterion. At increased altitudes, blood oxygen saturation falls off rapidly. At an altitude of 18,000 ft., oxygen saturation reaches about 70 per cent, a level of deprivation serious enough to produce unconsciousness.

Average time of useful consciousness[1] as a function of decreasing altitude is shown in Fig. 3.

Spotchecking the figure, it can be seen that useful consciousness while breathing ambient air represents no particular problem until levels of over 15,000 ft. are reached. At 20,000 ft. it is still a matter of minutes until the advent of unconsciousness; at 25,000 ft., a little less than 3 min.; at 30,000 ft., 70 sec.; at 40,000 ft., 23 sec.; and from 50,000 ft. upward, about 15 sec.

To overcome oxygen deprivation resulting from decreased atmospheric density, the following procedures may be utilized, as shown in Fig. 4. For the purpose of comparison, the first vertical bar depicts the situation if the airman is breathing ambient air. He shows no symptoms of oxygen deprivation before reaching a

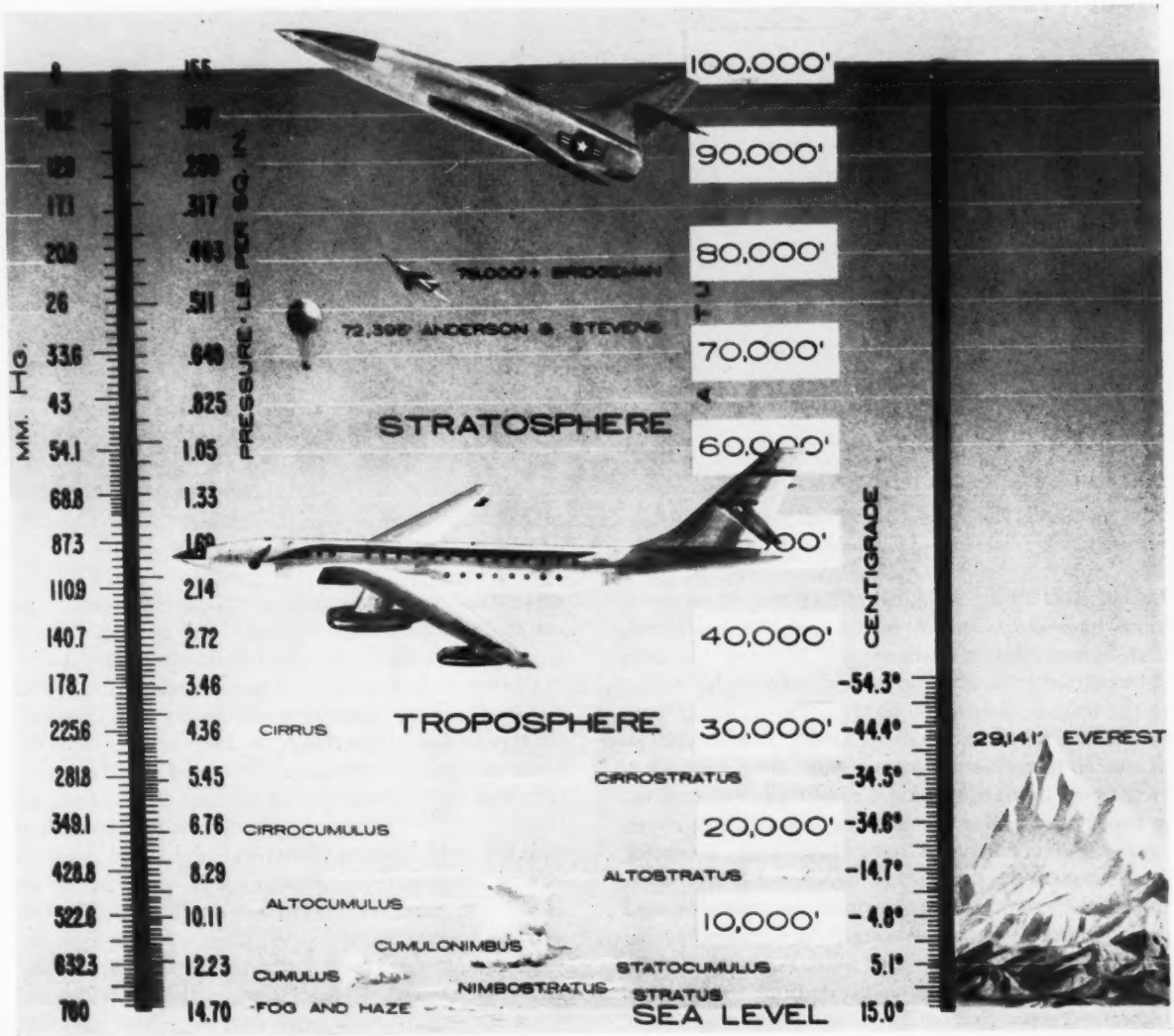

FIG. 1. Basic characteristics of atmosphere from sea level to 100,000 ft. showing atmospheric pressure and temperature variation as a function of altitude.

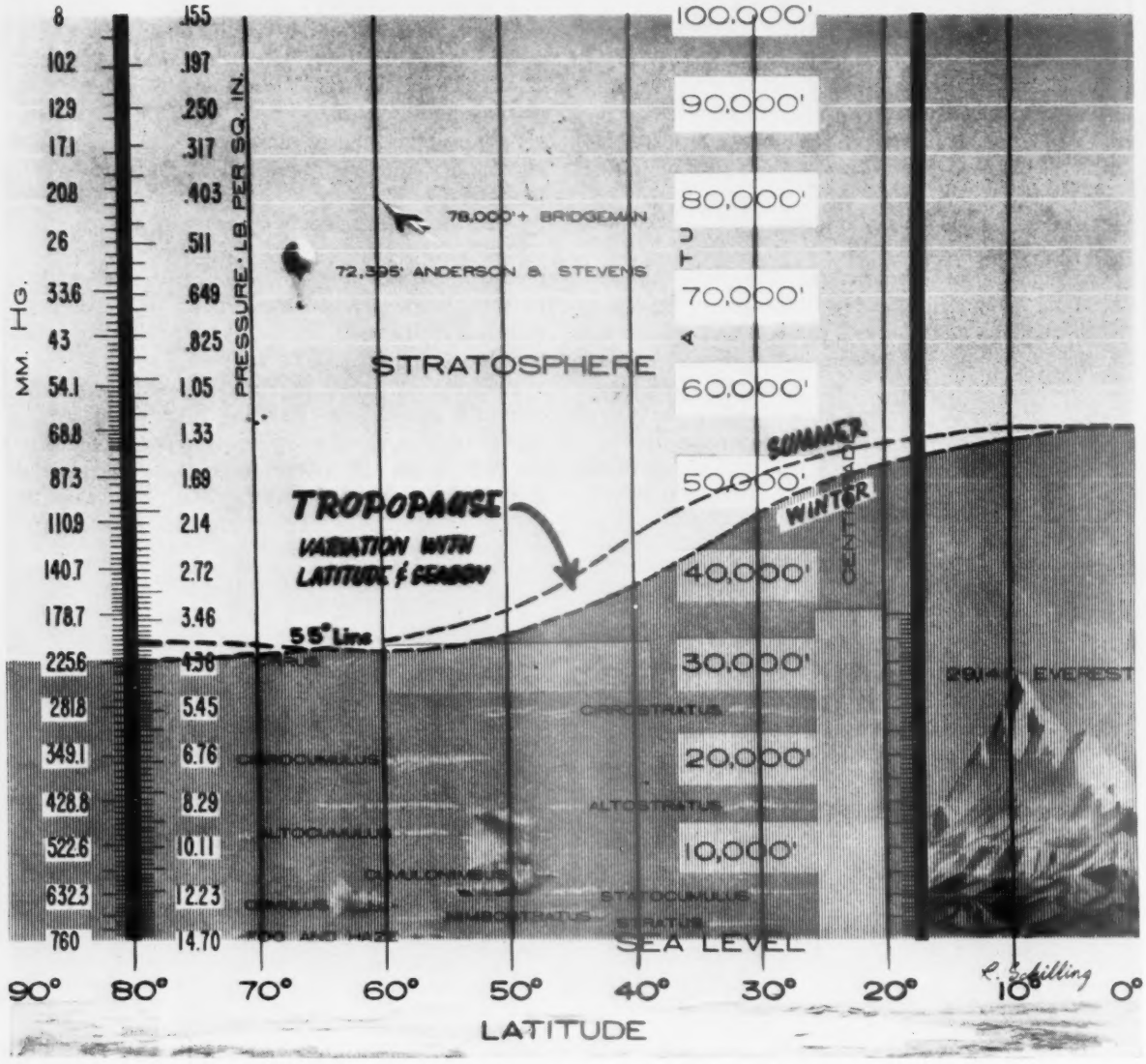

FIG. 2. Variations of tropopause with season and latitude. Hatched area represents troposphere.

level of 10,000 ft. At 18,000 to 20,000 ft. he may become unconscious. The second vertical bar shows that, by using 100 per cent oxygen delivered through a tightly fitted oxygen mask, he may increase his ceiling to the neighborhood of 39,000 ft. The third bar demonstrates a relatively small altitude gain to 42,000 ft. which can be produced by increasing the oxygen mask pressure to 12 in. of water (25 mm. Hg). This ceiling is about the limit we can expect from conventional oxygen systems alone. Above these levels, according to the fourth bar, pressurization of the immediate environment of the man becomes necessary. Cabin pressurization requires a compressor system and a sealed compartment. In the altitude range 70,000–80,000 ft., the lower density of the atmosphere makes adequate compression uneconomical in terms of weight of the compressor. Above this altitude, as shown by the last bar, a sealed cabin must be employed. Such a cabin must have adequate initial pressure and must maintain it throughout the trip. Dr. Luft's paper, on page 56 of this issue, gives further details in this area.

The lowering of barometric pressure results in another biological effect, generally designated as "bends." This pathological condition is due to the release of blood nitrogen into the body tissues and closed cavities. Although the occurrence of bends has certain of the aspects of chance phenomena, it certainly is correlated with rapidity of ascent, altitude attained, and duration of stay at altitude. Symptoms may occur as low as 23,000 ft. Maintenance of adequate pressurization answers the problem.

Altitude is also associated with the biological stressor—cold. Speed is associated with the biological stressor—heat. Temperature falls with altitude, reaching approximately −55° C. at the tropopause. As shown in Fig. 5, there is little variation of the tempera-

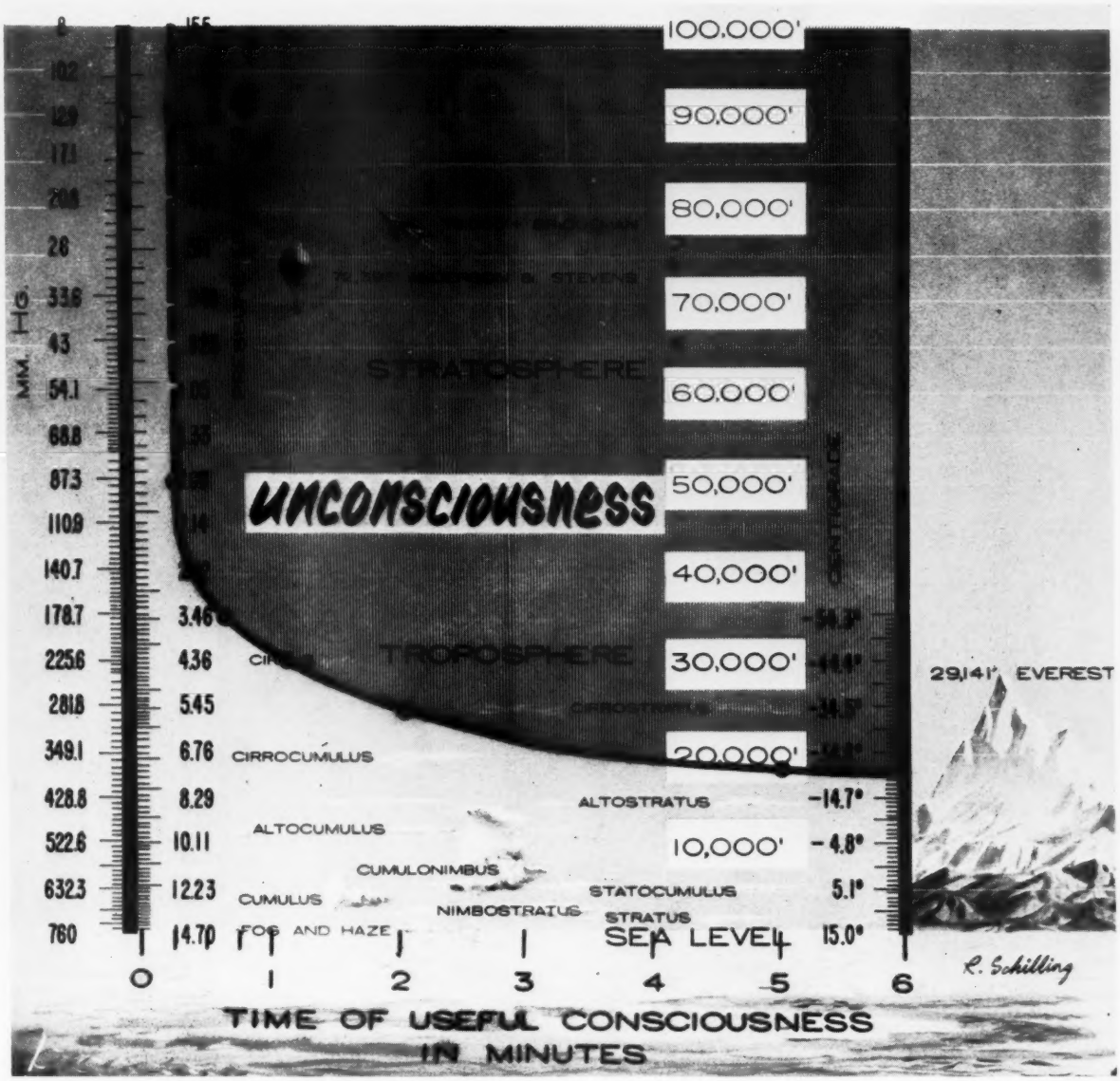

FIG. 3. Time of useful consciousness in ambient atmosphere for various altitudes.

ture range through the portion of the stratosphere between the tropopause and the 100,000-ft. level.

Ram temperatures increase roughly as the square of the speed of the aircraft. During flight in the higher speed craft, this factor much more than compensates for the low ambient temperatures. Turning to our original parameters, the temperature of the surface air would be of the order of 0° F. for the 50,000-ft., 600-m.p.h. craft, but 650° F. for the ram-air heating the surface of the 100,000-ft., 2,000-m.p.h. sealed cabin craft.

The ozone of the atmosphere[2] occurs in appreciable quantities at altitudes of 60,000 to 100,000 ft. Its presence is due to the photodissociation of the oxygen molecule O_2 into oxygen atoms by ultraviolet sunlight. If inhaled in sufficient concentrations, it is known to have toxic effects. Approximate concentrations of ozone as a function of altitude are shown in Fig. 5. Units on the horizontal axis represent ozone density in the mid-latitudes in terms of centimeters per vertical kilometer of altitude if all were in a single layer.

Compression of ozone into aircraft cabins could present human problems. The sealed-cabin type of aircraft, however, should afford the solution. The ozone layer of the atmosphere filters out by far the greater part of the more biologically deleterious bands of ultraviolet light that affects skin and eyes. This protection is absent above the ozone layers.

In conclusion a word must be said concerning heavy primary radiation of cosmic origin.[3] According to present knowledge, cosmic rays appear to be ultra-high-speed particles arising from undetermined extraterrestrial sources. They possess energy in excess of billions of electron volts, and at least some of the particles are capable of producing nuclear disintegration. Secondary rays, tertiary rays, and mesons are produced after

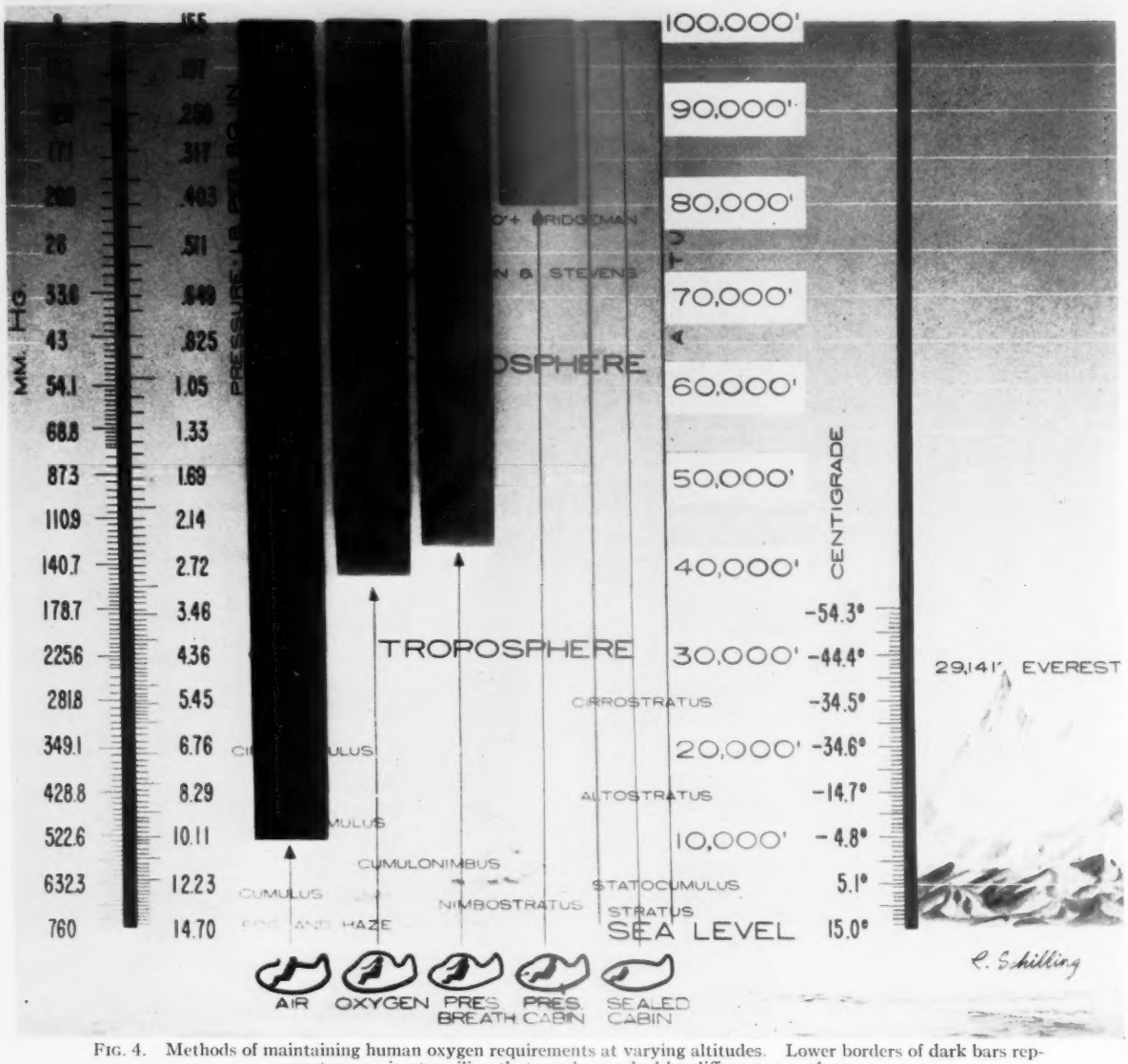

FIG. 4. Methods of maintaining human oxygen requirements at varying altitudes. Lower borders of dark bars represent approximate ceiling that can be reached by different procedures.

entrance into the atmosphere, sometimes resulting in cosmic-ray showers in the denser parts of the atmosphere. Such activity, due to the filtration effect of the atmosphere, decreases as the earth is approached, and at sea level there is only about 0.03 of that present at the altitude of the ozone layer. The few cosmic rays that strike the surface of the earth are of sufficient velocity to penetrate several hundred feet into it.[2] There are still broad gaps in our knowledge of the biological effects of the primary cosmic particles; however, one must expect them to act somewhat similarly to radiation of the alpha particle type—that is, quick energy dissipation with high concentrations of ion pairs along short tracks.

Definite assessment of this problem must await considerable study; however, in light of present knowledge,[4] it can be stated with an acceptable degree of certainty that flights below 60,000 ft. will present no serious hazard and, with minor reservations, that flights between 60,000 and 100,000 ft. of the brief durations that can be expected during the next decade will probably be without unusual biological effects from cosmic rays.

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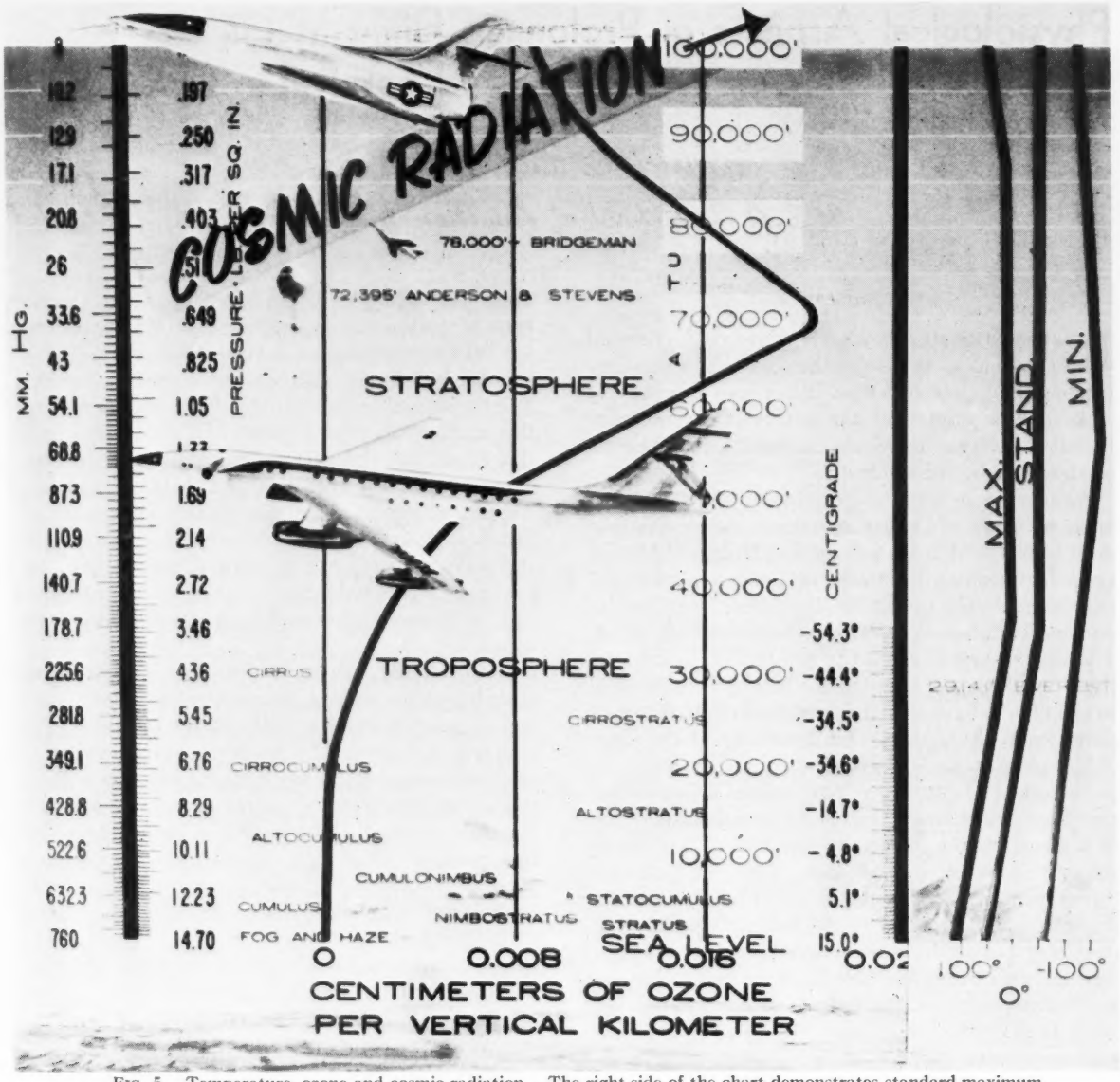

FIG. 5. Temperature, ozone and cosmic radiation. The right side of the chart demonstrates standard maximum and minimum temperature changes as a function of altitude. The central area represents the thickness of ozone layer in fractions of centimeters, as would result if all of the ozone in each kilometer of altitude were compressed at 1 atmosphere of pressure. Cosmic radiation becomes a possible hazard above 60,000 to 70,000 ft.

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Physiological Aspects of Prolonged Flight at High Altitudes and Survival in Emergencies

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Introduction

In order to ensure the most effective and economical integration of protective devices and emergency equipment in aircraft design, it has been necessary to make specific studies of the nature of physiological limitations imposed by the unusual environmental conditions to be encountered.

Before entering into the special aspects involved, it is appropriate to emphasize significant differences that must be observed in the judgment of biological data, in general, as compared to those pertaining to physics and engineering. The first is the astonishing degree of individual variation in tolerance to stress of any kind. The second, closely related to the former, is the relatively wide range of adaptability within the individual to conditions that are on the borderline of physiological competence. Whereas precise knowledge of the range of human tolerance is essential where the realization of physiological adaptations may mean the difference between life and death in emergency situations, it would be a grave mistake to encroach upon these faculties in the routine operation of aircraft. Even minor physiological compensations in response to heat and cold, to the effects of altitude, or to the forces of acceleration, inevitably detract from the individual's vital reserves, leaving him more susceptible to other forms of stress and hastening the onset of fatigue. From this point of view, the design of compartments for crew and passengers on extended flight at high altitude must be intent upon maintaining conditions compatible with mental and physical integrity of the occupants for an indefinite period of time. In addition to this, the best possible precautions must be taken to contend with emergencies whereby physiological tolerance may have to be exploited to the utmost for a limited period of time.

Temperature and Humidity

It has been established for widely different occupational activities that the best physical and mental performance is obtained when the environment is controlled within a limited range of temperature and humidity. Fig. 1 represents the "comfort zone" for an average group of individuals living in a temperate climate in sedentary activity.[1] This area is naturally subject to change according to the state of activity and the amount of clothing. In general, however, temperatures of less than 15° C. are uncomfortable regardless of the humidity, while, at temperatures above 20° C., comfort is definitely affected by the relative humidity. For the sake of simplicity, the effective environmental temperature has been expressed as air temperature in this graph. Strictly, this holds only in the absence of air movement or loss of heat by radiation. The latter component may become disturbingly perceptible, for instance, in an aircraft ventilated with warm air while the walls remain close to outside temperature, thus producing a gradient for heat loss by radiation from the body if thermoinsulation of the compartment is inadequate.

Until recently, the air conditioning of high-altitude craft has been concerned primarily with a heating problem in view of the low ambient temperatures. The high speeds developed by jet- and rocket-propelled aircraft now confront the aeronautical engineer with the task of protecting the occupants against the high temperatures produced on the surface of the ship by impact and friction of air at high velocities, the so-called aerodynamic heating. Fortunately, conditions are somewhat more favorable at extreme altitudes due to the reduction of heat transfer with lower air density. Certainly, refrigeration will be necessary when supersonic speeds are sustained long enough to produce a tempera-

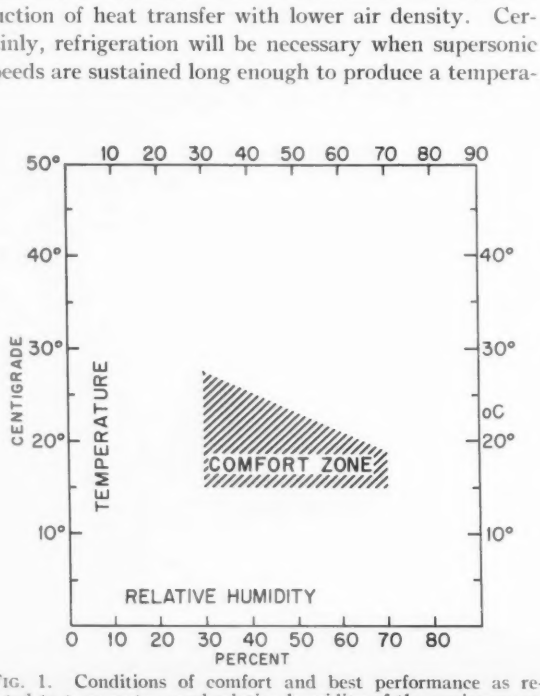

Fig. 1. Conditions of comfort and best performance as related to temperature and relative humidity of the environment.

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ture equilibrium in the aircraft. Critically high temperatures are also generated by the compression of ambient air at high ratios required in the cockpit or passenger compartments. In an aircraft flying at 60,000 ft. with a cabin pressure of 10 pounds per sq.in. absolute, the air temperature at the compressor outlet will be approximately 250°C.[2] Failure of the cooling system would immediately expose the occupants to intolerable heat. The tolerance time for extreme heat at an average humidity of 30 per cent[3,4] is shown in Fig. 2. The experiments reported by Blockley, Taylor, and Buettner were terminated at a point where definite signs of heat exhaustion, such as nausea and mental dullness, occurred and collapse was imminent.

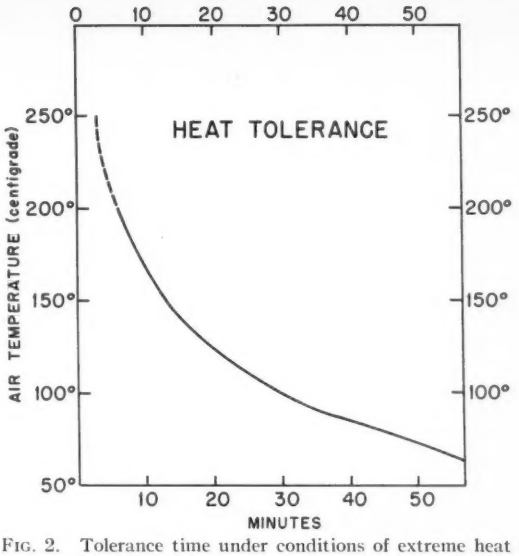

FIG. 2. Tolerance time under conditions of extreme heat at an average humidity of 30 per cent in light clothing (after Blockley and Taylor, Buettner).

CABIN PRESSURE

The necessity for the use of pressurized cabins to protect crew and passengers from the effects of low barometric pressure has been generally accepted by civil and military aircraft today.

From a physiological point of view, it would appear desirable to provide the aviator with a cabin environment that resembles conditions on the earth's surface as closely as possible in complete independence of altitude and duration of flight. In practice, a compromise must be made in the choice of cabin pressure, depending upon the type of aircraft and its mission, in due consideration of technical-structural expedience and physiological requirements. The latter are based upon extensive aeromedical research and practical experience regarding the essential partial pressure of oxygen in the inspired air and the minimum total pressure necessary to prevent manifestations of decompression sickness, such as bends, chokes, etc.

Three typical situations may serve to illustrate this. If the use of individual oxygen equipment is undesirable or impracticable, the absolute cabin pressure should not be less than 10 pounds per sq.in., which is equivalent to an altitude of 10,000 ft. (Fig. 3, A). This provides an oxygen pressure of about 100 mm. Hg in the inspired air that is saturated with water vapor at body temperature when it enters the lungs. Where supplementary oxygen is used, the cabin pressure may be reduced to 6 pounds per sq.in. without embarrassment by decompression sickness for an indefinite period of time (Fig. 3, B). The third column in Fig. 3 indicates that a minimum pressure of 3 pounds per sq.in. is tolerable provided that pure oxygen is inhaled. This situation, however, will result in a high incidence of bends unless the occupants have had opportunity to eliminate most of the gaseous nitrogen from their blood and tissues by breathing oxygen for a considerable time before take-off or in preceding phases of the flight. Obviously, the last case is not applicable to civil aviation and will be limited to emergencies in military aircraft.

It is noted that the figures given here for minimum cabin pressures are in terms of absolute pressure regardless of flight altitude. The pressure differential exerted upon the walls of the cabin and the pressure ratio

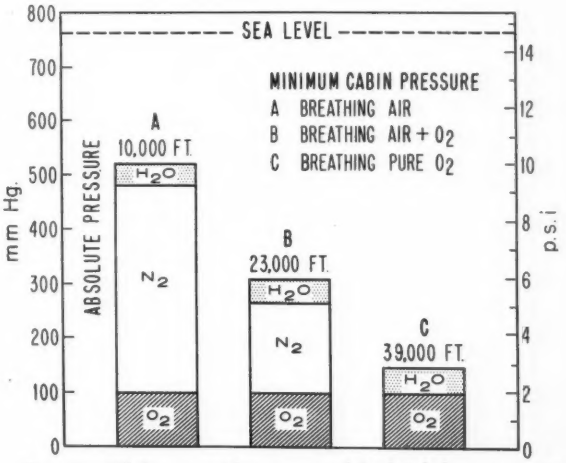

FIG. 3. Minimum cabin pressure (absolute) for occupants breathing air (A) using oxygen equipment to maintain an adequate partial pressure of oxygen at a cabin pressure sufficient to prevent decompression sickness (B) and when inhaling pure oxygen. (C) Equivalent altitude and the partial pressures exerted by water vapor at body temperature of nitrogen and oxygen are indicated for each column.

required of the compressor system then become functions of altitude. These variables are related graphically in Fig. 4 by plotting cabin pressures and equivalent altitudes against ambient atmospheric pressure and flight altitude. Ascent without cabin pressure would follow the diagonal at a 1:1 ratio. The verticals A, B, and C correspond to the three columns in the previous graph and represent isobaric conditions in the cabin for 10 pounds per sq.in., 6 pounds per sq.in., and 3 pounds per sq.in., respectively. The pressure differential and compression ratio for any flight altitude is found at the intersect with the desired cabin altitude. It has already been mentioned that compression of ambient

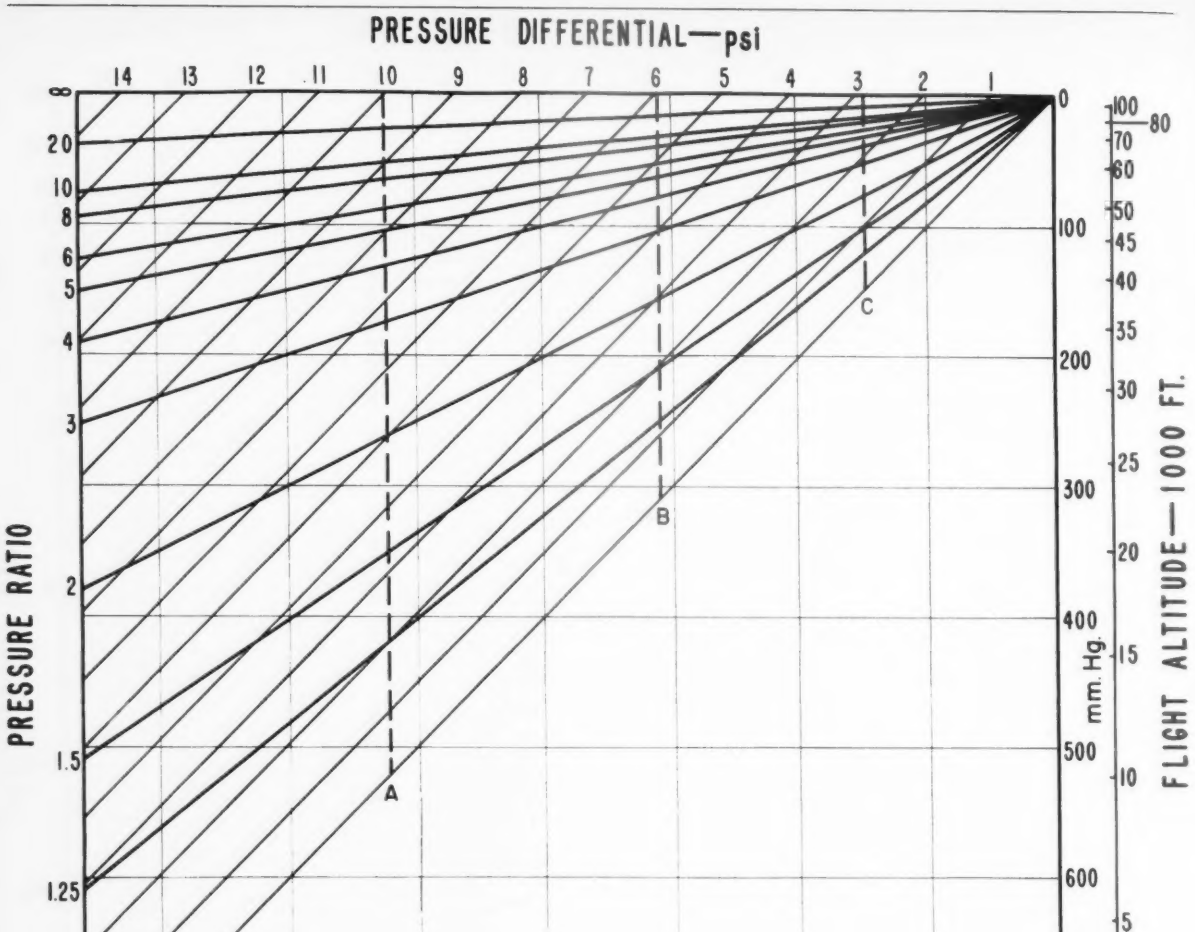

FIG. 4. Pressure differential and pressure ratio a function of flight altitude for cabin isobarics A, B, and C corresponding to the columns in Fig. 3.

air by mechanical means becomes impractical at altitudes above 60,000 ft. because of the excessive pressure ratios required. A compression of 25:1 would be necessary to maintain 10 pounds per sq.in. in a cabin at 80,000 ft. For these conditions, a self-sustaining source of pressure must be incorporated into a completely sealed cabin, a situation that involves further physiological problems, such as the continuous replacement of oxygen consumed and the elimination of excess water vapor and carbon dioxide generated by the occupants. The question again arises in this connection whether individual oxygen equipment should be employed, thus making the aviator independent of the composition of cabin air, or, whether for reasons of comfort and freedom of movement, the entire cabin environment should be regenerated following the principle used in submarines.

SUDDEN DECOMPRESSION

So far, we have emphasized the advantages of maintaining a high cabin pressure, both for physiological reasons and for the convenience of obviating oxygen equipment in aerial travel at high altitudes. It must not be overlooked, however, that the higher the existing pressure ratio, the greater are the hazards encountered in the event of sudden loss of cabin pressure due to mechanical failure or enemy action, particularly when oxygen is not instantly available.

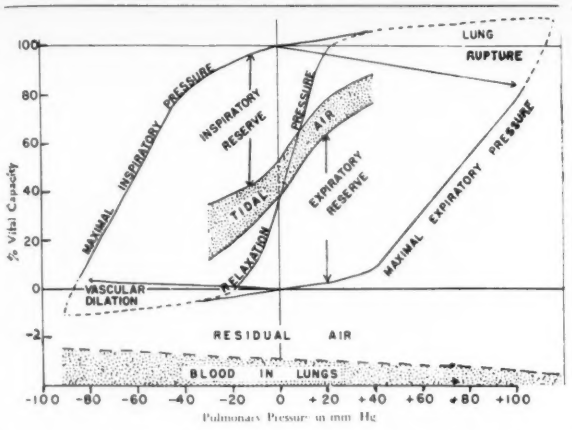

FIG. 5. Pressure volume diagram of chest and lungs indicating danger of rupture under high pressures when the lung is distended.[5]

It is important to distinguish between the immediate physical-mechanical effects of rapid or explosive decompression and the results of exposure to extreme lack of oxygen. The severity and possible dangers of the physical impact of decompression depend upon the magnitude of the pressure change and the rate of decompression. Gases that are present in body cavities immediately tend to expand in proportion to the loss in ambient pressure. Where this tendency to expand is contained and the escape of gas is obstructed, excessive pressures may result. This applies to the intestinal tract, which contains gas at all times, and particularly to the lungs. The latter are more susceptible to pressure due to the delicate structure of pulmonary tissue. The following diagram [5] (Fig. 5) describes the pressure-volume relationships and physical tolerance of the mammalian lung when subjected to increasing negative and positive pressures. Pulmonary damage is imminent whenever pressures of more than 80–100 mm. Hg occur and the lung is distended beyond its normal capacity. The results may be a traumatic pneumothorax and also aeroembolism into the blood vessels. Fortunately, such an event is to be expected only under the most extreme conditions of explosive decompression when the escape of gas is obstructed—e.g., by "breath-holding."

Much of the original apprehension regarding the dangers of rapid decompression has been dispelled by practical experience obtained in low-pressure chambers where decompression under adverse conditions has been well tolerated as fast as $^1/_{100}$ sec.[6] This hazard may be further reduced by protective garments to restrict overexpansion of the chest in decompression.[7]

While the mechanical effects of decompression will seldom be incapacitating, the menace of coincident hypoxia becomes the most formidable single factor with increasing operational altitudes. Fig. 6 presents experimental data on the time of consciousness following loss of cabin pressure when breathing air (lower curve) and when breathing pure oxygen at various flight altitudes. Both curves converge toward a minimum of about 15 sec. at 50,000 ft. This short period evidently represents a latency or free interval which can be ex-

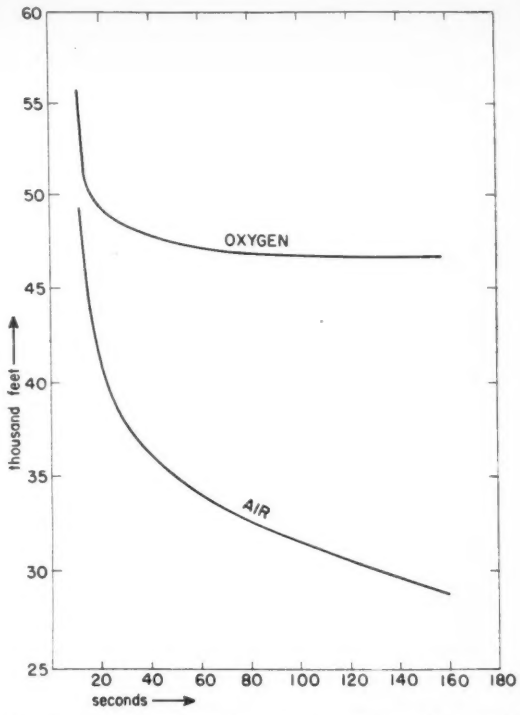

FIG. 6. Time to unconsciousness due to hypoxia on sudden exposure to high altitude by loss of cabin pressure. Lower curve: breathing air. Upper curve: breathing oxygen.

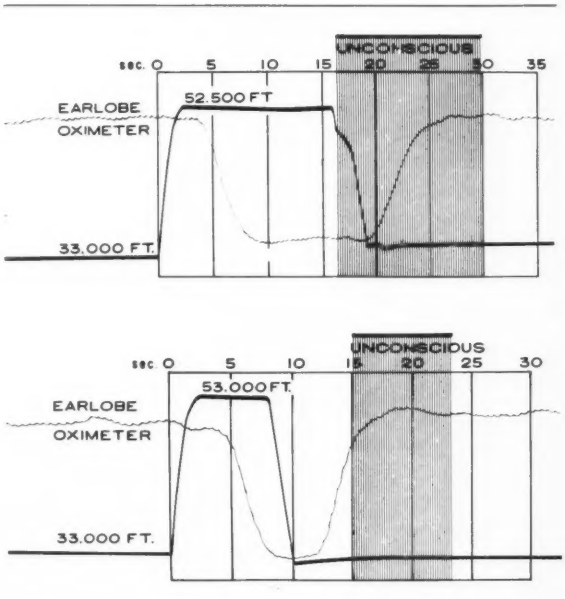

FIG. 7. Photoelectric recording of blood oxygen saturation (oximeter) during and after rapid decompression from 33,000 to 52,500 ft. breathing pure oxygen. Recompression was performed at the onset of unconsciousness: 16 sec. Lower graph presents similar procedure but with recompression after only 8 sec. exposure to 53,000 ft. Unconsciousness occurred after return to 33,000 ft. with adequate oxygen.

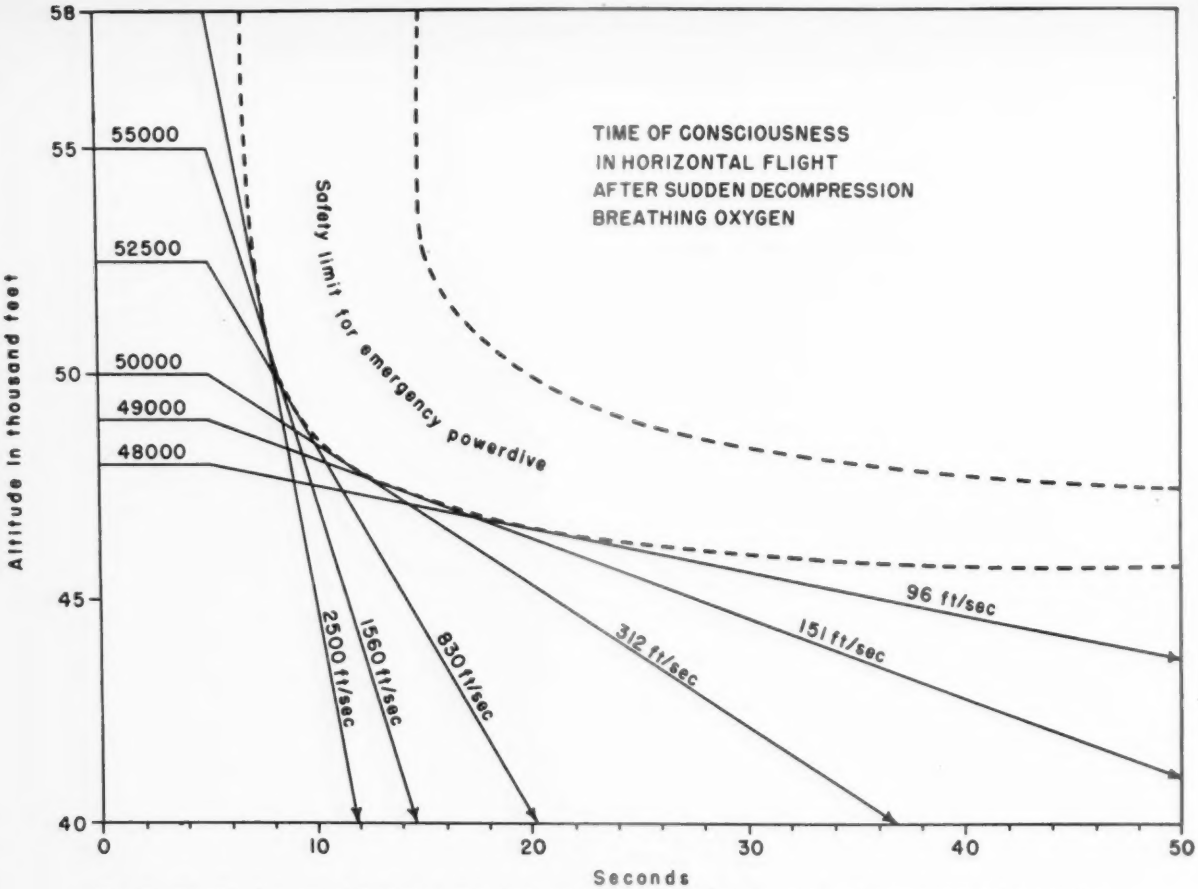

FIG. 8. Family of curves originating at altitudes from 48,000 to 55,000 ft. shows rate of descent required to avoid unconsciousness after loss of cabin pressure when breathing oxygen.[8]

plained partly by the time required for blood to travel from the lungs to the brain and partly by energy reserves in the cerebral cells. The reproduction of an original experimental record allows an analysis of the course of events (Fig. 7). The lower record also demonstrates that unconsciousness occurs after the said free interval, even though the exposure to an altitude of 53,000 ft. lasted no longer than 8 sec. An aviator stricken by sudden loss of cabin pressure at this altitude would have to execute a power dive at the speed of sound in order to reach safe altitudes with oxygen before loss of consciousness.[8] (Fig. 8). This example serves to stress the necessity of emergency equipment such as a pressure suit that is automatically controlled to become effective within a few seconds. Such an emergency pressure garment has been developed to meet these requirements by the Aeromedical Laboratory of the Air Force and has recently been described in the press. It has been tested successfully in the low-pressure chamber at altitudes well exceeding those attained in the record-making high-altitude flights during which the partial pressure suit was worn.

Escape from Aircraft

The hazards of escape from aircraft traveling at high speed have lead to the development of the ejection seat designed to propel the aviator clear of the fuselage and its protuberances either in upward or downward direction.

New physiological problems have arisen in this area regarding human tolerance to high accelerative forces experienced during ejection and to wind blast and deceleration encountered in the slipstream, and, subsequently, in the opening shock of the parachute. Practical experience with the ejection seat in its present form gives confidence that it can be used for escape from aircraft at velocities up to Mach 1. The possibility of injurious effects resulting from wind blast and deceleration in separation at supersonic speeds will probably necessitate more complete protection of the man by enclosing him in a capsule or pod with more favorable aerodynamic qualities.

Conclusion

Steady, if laborious, progress is being made in physiological research to meet the challenge presented by the technical advancements in operational speed and altitude. Each new type of aircraft poses its own peculiar problems regarding safety of passengers and crew. In many instances common solutions can be found for

(*Concluded on page 68*)

Vision

at High Speed and Altitude

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Introduction

This presentation is concerned with those visual problems produced by high altitude and high speeds. We must therefore know the specific altitudes and speeds being considered. For the purposes of this presentation the following ranges are believed to be realistic limits for the next decade:

Speeds.—Civil air transport; just subsonic. Military aircraft; up to 2,000 m.p.h.

Altitude.—Civil air transport: actual altitude not over 50,000 ft.; cabin altitude 8,000 ft. Military aircraft: actual altitude 100,000 ft.; cabin altitude 37,000 ft., maximum.

Illumination

The visual problems to be encountered will be those produced by the physical environmental factors present. Of these the light present will be an important consideration. We must know the type and amount of light present and the distribution of that light at various altitudes.

The sun produces light in all wave lengths, but the intensity of this light is very small above 2,100 millimicrons or below 50 millimicrons. All wave lengths are filtered somewhat by the atmosphere of the earth—some much more than others. The illumination in space is about 13,600 foot-candles. At the surface of the earth on a clear day it is about 10,000 foot-candles. In addition to this general atmospheric attenuation, certain wave lengths are filtered selectively. The ultraviolet light in wave lengths up to 200 millimicrons is filtered out by dissociated oxygen 400,000 ft. and above. The 200–300 millimicron band is filtered out by the ozone layers. There are usually about two such layers one around 70,000 ft. and the other around 120,000 ft. Above 120,000 ft., the concentration of these ultraviolet wave lengths increases rapidly. This band includes the 288–292 millimicron band that is extremely damaging to the eye. It is the wave length band that produces the severe kerato-conjunctivitis associated with welding. At 100,000 ft., these wave lengths present problems not much more severe than at ground level. However, if flights are contemplated above 120,000 ft., it will be necessary to make sure that pilot and passengers have eye protection against these wave lengths.

Thus, at altitudes up to 100,000 ft., we have qualitatively the same kind of light we have at ground level, but quantitatively we have a progressive slight increase with increasing altitude. Above 40,000 ft., the amount of this increase will be slight.

The distribution of the light changes continuously as one ascends. Light is scattered by molecules of air, dust particles, and moisture. This makes the sky look bright and gives the scattered light that enables one to see objects well even when sunlight does not fall directly on them.

The greater the altitude, the fewer particles present in the air, and thus there is less scattering. The sky appears darker, and there is less light on the instruments and inside the cabin. Contrasts inside airplanes become extremely large. Measurements may show a ratio of 1 to 60,000 or more between the brightest and the dimmest portion of an exposed area. However, the sky does not get black as fast as the science fiction articles suggest. For example, one must get to 300,000 ft. or above to reduce the brightness to that of a moonlit sky. The problems presented by this distribution of light can be considered, then, under three headings:

(1) What can the pilot see so far as other aircraft are concerned?

(2) What can the crew see inside the cockpit?

(3) What can the passengers see inside the cabin?

The pilot problem with regard to seeing other aircraft is intensified. If the other aircraft is seen as a dark silhouette against the dark sky, it will obviously be more difficult to distinguish than at ground level. If seen by specular reflection, it may be seen from extreme distances because of the extremely clear air. Unless it is in a position to reflect like a mirror, however, it may be difficult to see even though the sun is shining on it This is true because there is little scattered light to illuminate the plane, and, again, it may still only be seen as a dark silhouette against the sky. This represents a real problem for the military pilot at our present operational altitudes. It will become more acute at the higher ones.

Under these conditions of reduced sky brightness, instrument visibility is reduced. This is particularly true of recessed instruments. It is made even worse

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when the sun is shining on the nose or wind screen. The individual is then trying to discriminate instrument markings when there are brighter objects in his visual field. Such visual discriminations are always difficult to make. One sees best when the item of regard is a little brighter than its surrounding area. The solution to this problem probably lies in low reflectance coating on the nose and other exterior portions of the aircraft within the field of view and the use of light-reflecting paints in the cockpit to reflect the light that is present on the instruments. Also of benefit would be the use of high-intensity instrument lighting and, under some circumstances, use of specially shaped filters worn in front of the eyes to equalize the external brightness and that of the instrument panel.

The passenger problem is essentially one of inability to see well because of the dim light from the sky. Interiors must be extremely light to reflect the light that does enter. Brighter and better dispersed cabin illumination will be required for both reading and general illumination.

Hypoxia

If the criteria as set forth at the beginning of this paper are met, there should be no problem of vision produced by the lowered oxygen tension. The civilian air liner pressurized to a cabin altitude of 8,000 ft. will have no decrease in visual function other than a slight decrease in night vision. If the military aircraft is pressurized to 37,000 ft. and the pilot is breathing pure oxygen, this would be equivalent to about 8,000 ft. without oxygen. Again, he should have no defect in his visual function other than a slight decrease in night-vision ability. It should be recalled that the retina has the highest oxygen demand of any body tissue, and, therefore, it might well be expected to show the first effect of oxygen lack when the retina is operating at its maximum ability. This decrease in function is most easily measured when very dim light is used.

Dysbarism

The effects of lowered barometric pressure on the eyes will not become apparent at the 8,000-ft. cabin level of the civilian air liner. However, at the 37,000-ft. cabin level of the military aircraft, the decompression phenomena may occur. These are usually due to vascular spasms with decreased blood supply to portions of the visual apparatus. As a result, certain portions of the visual field are nonfunctional, and personnel may have blind areas, often accompanied by severe generalized symptoms. This whole problem of dysbarism will require consideration in flights to these extreme altitudes. An explosive decompression would increase this problem.

High Speeds

Assuming that speeds of 2,000 miles per hour may be attained within the next 10 years, the pilot of such craft will be faced with visual problems produced by a different type of airflow, by slanting optical surfaces, by vibration, by acceleration, by temperature, and especially by the lag in human visual perception time. In case of structural failure, he is faced with the possibility of being ejected into the air at high speeds with the further possibility of injury to his eyes by air blast. These problems will be considered under the following headings: (1) slanting optical surfaces, (2) visual distortion due to shock waves, (3) vibration, (4) lag in visual perception, (5) acceleration, (6) temperature, and (7) high-speed escape.

Bodies moving faster than Mach 1 have a wave built up in front of them. At Mach 1, this wave front is almost straight, lies rather far ahead of the moving body, and is not very dense. As speeds become faster, the wave forms a more and more acute angle over the nose of the body and becomes denser.

Effect of Slanting Optical Surfaces

In order to permit supersonic flight, the aircraft must be free of any projections and, therefore, optical surfaces must be slanted to produce the least possible drag. Bjornstad[1] studied this problem and found that currently produced bulletproof plate glass with a nesa coating could be slanted to an angle of 70° without producing measurable change in visual acuity or depth perception. The slant did not produce any measurable distortion and produced less than 3 min. of deviation. The simple displacement of images produced by slanting surfaces in which emergent rays are parallel to incident rays is not important. Chapanis and Schachter[2] showed that large angles impair depth perception in distorted glass less if tilted forward or backward rather than around a horizontal axis. The main effect of distortion of windshield glass is on binocular clues of depth perception. The nesa coating used to defrost the windshield would not be required at supersonic speeds but might be useful at slower speeds. It was shown to have no adverse visual effects.[1]

Visual Effects Produced by Shock Waves

Visual effects produced by the shock waves themselves are a problem. The air in these waves being optically denser than normal air produces a deviation of light rays with an apparent displacement of objects from their true position. Walchner and Rambauske[3] studied this phenomenon and demonstrated that it is not a theoretical concept but that it actually occurs. Its extent is small. It will, however, be a difficult one for which to compensate because it varies with the speed between Mach 1 and Mach 4 and is entirely absent below Mach 1. The flow of the air in the compression wave will obviously not be absolutely homogenous.

Vibration

Vibration has been a rather popular subject in articles on supersonic speeds in the press. The spectacular effects produced by ultrasonic generators have been

shown. Actually, no vibrations of intensities great enough to harm human eyes have been produced by either jet-or rocket-propelled craft. One effect vibration may produce on the eye is resonation at its own frequency of about 40 cycles per sec. This low-frequency vibration will blur vision. Actually, such resonance is much more readily produced by vibrations of 10 to 40 cycles or 60 to 90 cycles than by high-frequency vibration. Flight reports of supersonic speeds state that transient blurring of vision is experienced as the barrier is passed. This is probably due to buffeting by the mixed airflow in the transonic speed range.

Lag in Visual Perception

The length of time between an actual occurrence and the time an individual sees it depends upon the length of time required for light to reach the eye and the conduction time in the visual pathways and brain tracts. The speed of light is so fast that as a factor it can be ignored. The lag in the visual mechanism, however, is appreciable and at supersonic speeds is important. Strughold[4] has recently reviewed the literature on these conduction times, and Noell and Chinn[5] obtained similar figures in electroretinographic and electroencephalographic studies.

This perceptual latent time covers the period required to stimulate the receptor, conduct the nerve stimulus over the centripetal pathway, and reach an excitation level in the cortex. Recognition time, decision to act, and motor impulses to muscles must all be added before reaction occurs. The latent period of perception varies with the intensity of the stimulus, the part of the retina stimulated, and the characteristics of the individual, including his state of attention. This latent perceptual period may vary from 0.035 to 0.300 sec.

These sensory conduction times are of importance at supersonic speeds because of the distances traveled during them. If an individual is flying 1,800 m.p.h. (Mach 2.39 at sea level), he is traveling 2,640 ft. per sec. or roughly a mile every 2 sec. If an object suddenly appears in his peripheral field of vision, he will not be aware that there is an object present for about 0.1 sec. During that time, his aircraft will have moved 264 ft. In order to see the object clearly, he must set up an eye muscle movement of predetermined distance. This will require about 0.175 sec., during which time his plane will have moved 462 ft. The actual movement of his eyes (about 25°) will require an additional 0.050 sec., during which he moves another 132 ft. His visual axis is now fixed on the object he wishes to see, but foveal perception time will add another 0.070 sec. with another 185 ft. Thus, from appearance in the peripheral visual field until the object is seen by central vision, about 0.400 sec. will have elapsed and the aircraft will have traveled 1,042 ft. The individual has not yet recognized the object, he has only seen it. Recognition time varies between 0.650 to 1.50 sec., so an average would probably be 1 sec.; during which time an additional 2,640 ft. will have been traveled, making a total from appearance to recognition of 1.400 sec. and the distance 3,682 ft. This does not include the time required to make a decision to do something about it or the motor reaction time required to move the control surfaces. Assuming such motor reaction time to be about 0.400 sec., this would add another 1.042 ft. for a total distance from extrafoveal appearance to control movement on the aircraft of 4,724 ft. Thus, it is obvious that, if two aircraft emerged from clouds 3,000 ft. apart coming toward each other, they would collide before either pilot could do anything about it. If they came out of clouds head on at a distance of 500 ft., they would collide without either pilot having seen the other.

Speed of accommodation becomes an important factor in looking down at the instrument panel and then back to distance. Since accommodation is a smooth muscle phenomenon, it is relatively slow in comparison to movements of the striated extraocular muscles. For example, in deciding to look at the instrument panel, a muscle movement of predetermined extent requires 0.175 sec. (462 ft. at 1,800 m.p.h.) for establishment of the reflex. The eye movement itself requires 0.050 sec. (132 ft.). Accommodation may vary from 0.15 to 1.2 sec., so an average of 0.5 sec. would allow travel of 1,320 ft. Foveal perception requires 0.070 sec. (185 ft.) and recognition, since the material is familiar, requires 0.800 sec. (1,952 ft.). Then to look back again to distance, the requirements are: reaction time, 0.175 sec.; eye movement, 0.050 sec.; relaxation of accommodation, 0.50 sec. (may vary from 0.39 to 0.82); and foveal perception, 0.070 sec. This would give a total time from clear distance vision, to reading a dial with recognition, and returning to clear distance vision of about 2.39 sec., during which the plane would cover 6,336 ft. Actually, some of these functions occur simultaneously so that the time in a young individual will be shorter, about 1.5 sec., or a total distance of 3,960 ft. It is because of such problems that maximum readability of instrument dials is necessary and has recently received so much study. One present effort to have all dials with pointers reading horizontally and forming a line when the aircraft is performing normally is obviously justified. Time of accommodation increases with age and may be doubled in a man 50 years of age as opposed to one of 25 years. This fact is important when pilots are selected for these high-speed craft.

In two aircraft approaching head on, the distance at which planes can be identified is important. Assume that the pilot has 20/15 vision that enables him to discriminate a visual angle of 45 sec. of arc. An F-80 fuselage will just fill this angle at a distance of 4 miles. The pilot may see a speck in the sky at distances greater than this but will be unable to discriminate its details more than 4 miles away. If both aircraft are flying 1,800 miles per hour, neither pilot will have more than 4 sec. from maximum point of recognition to collison. Subtracted from this time must be that of the latent perceptual times mentioned above. In addition there is the problem of abruptly changing the course of a fast-moving aircraft with its strong gravitational (*g*)

forces. At these speeds, then, there will be almost no time for the use of offensive or defensive armament as we have known it in past wars.

Recognition of unexpectedly seen objects may require more time, and thus the aircraft would cover more distance than in examples given above. These latent perceptual times become important in flying supersonic craft. They are one of the good reasons for installation of electronic devices that can react much faster than man to control the aircraft.

Acceleration

Angular accelerations occur in aerial movements such as a pull-out from a dive or in a turn. In a pull-out from a dive, the individual is forced down into his seat and may experience a force on the seat equivalent to many times his real weight. If this force is equivalent to four times his body weight, it is referred to as 4*g*'s or four times the pull of gravity. In straight and level flight, there is a force of 1*g* on the seat. Higher *g* forces produce their stresses throughout all the body tissues. At 7.5*g*'s, for example, blood has the weight of molten iron. Pull-out from a dive produces positive *g* (head-to-seat force). In an outside loop (seat-to-head force), negative *g* is produced. Physiologic effects are complex and are not primarily ophthalmologic in nature; however, the symptoms that temporarily incapacitate the individual (blackout) are eye symptoms.

In head-to-seat forces (positive g) the blood is forced away from the head. When cerebral systolic pressure falls below 20 mm. of mercury, the retina becomes ischemic because the intraocular pressure now exceeds the vascular pressure and it collapses the arterioles. This ischemia produces a reduction first in the nasal field which then spreads entirely across the visual field until central vision is lost. The onset of this "greying-out" can be noted by the average observer at about 3–4*g*'s. He "blacks out," on the average, at about 4–5*g*'s.[6] Anything that can be done to raise the vascular pressure in his eyes will increase his *g* tolerance. This can be done by suits exerting pressure on his legs and abdomen to reduce pooling of blood. Such suits can raise *g* tolerance in the average individual 2.3*g*'s above his nonprotected tolerance. Tolerance to *g* force can also be raised by shortening the heart-to-eye distance by crouching or by assuming the prone position. The prone position shortens the heart-to-eye level distance about one-half and increases tolerance to about 12*g*'s.

This visual phenomenon is an extremely limiting factor, then, in sharp turns in aircraft. Forces of 6*g*'s will black out practically every upright observer unless he is wearing a good *g*-suit. Turns that produce 6*g*'s at various speeds were, therefore, computed to give an idea of the limiting effect that this phenomenon has on high-speed flight. Turns of the following radii would each produce 6*g*'s.

250 m.p.h.	686 ft.	1,000 m.p.h.	11,132 ft.
500 m.p.h.	2,740 ft.	1,500 m.p.h.	25,074 ft.
750 m.p.h.	6,170 ft.	2,000 m.p.h.	44,530 ft.

Thus, at a speed of 2,000 miles per hour, the pilot could not turn a circle smaller than 18 miles in diameter, unless wearing a good protective suit or assuming a position other than upright, without being blacked-out all the way around the turn. Aerial combat under such conditions would be extremely difficult.

Temperature at Supersonic Speeds

It has been estimated that an aircraft traveling at 2,000 m.p.h. would develop a surface temperature about 600°C. In order to operate such craft, efficient refrigeration apparatus would have to be used. In the event of failure of such refrigeration, the eyes could withstand air of at least as high a temperature as a human can breathe, which is about 240° F. (116° C.). Individuals can withstand such temperatures and function for about 15 min. Absolute limit of tolerance at 240° F. is about 23 min.[6]

High-Speed Escapes

Aircraft flying at very high speeds will be subject to mechanical failure. No ejections of individuals from aircraft traveling at supersonic speeds have yet been reported. However, individuals have been subjected to air blasts of 530 m.p.h. for short periods up to 2 sec. without damage to the eyes,[7] and there have been escapes from aircraft at over 500 m.p.h. The human body free in air slows down to much lower speeds within a short period of time. In these escapes, the eyelids are forced open, but no resultant damage has occurred to the eyes themselves. The exact point of tolerance has not been determined, but it is probable that tearing of facial tissues would occur at speeds much higher than 530 m.p.h.[8] At supersonic speeds, individuals will probably require ejection in some type of protective capsule.

Discussion

An attempt has been made to outline the visual problems that will occur in future flights at very high altitudes and high speeds. Included have been the intensity, wave length, and distribution of the light present; oxygen-concentration effects; barometric-pressure effects; and high-speed effects. These items require consideration in the design and operation of such future high-performance aircraft.

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NOISE

A Problem in Air Transport and in Ground Operation

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U.S.A.F. School of Aviation Medicine

Introduction

The noise problem in aviation is not really a new situation, but rather it has been with us almost from the beginning of powered flight. Until recently, the added increments to the overall noise picture over the past few decades have been too small to jar us out of our complacency. Production of energy by any machine has always resulted in two by-products—heat and noise. Both the proportion and the absolute quantity of heat liberated from all engines have always been very high, and as a consequence the hazard from heat was early recognized and respected. On the other hand, the proportion of the energy from fuel liberated as noise has always been very small. As a consequence the noise hazard has been overlooked and ignored while the power output from engines was low. In the jet-aircraft engine of today, about 90 per cent of the fuel energy is released as heat and about $^1/_2$ per cent as noise. Even so, the total power release has now become tremendous, and the noise output has quickly gone into the dangerous levels. It is no secret to say that we are now well into the painful and dangerous levels of noise above 140 db. This increase in the logarithmic scale of intensity represents a tremendous increase in the noise energy received by the ear.

The Nature and Characteristics of Aircraft Noise

As in the medical study of disease, physicians feel that it is best to begin with causes and sources. Thus, in a discussion of aircraft noise, it is best to begin with the source of the noise, the aircraft. Jet aircraft generate noise principally from their power plant and by their passage through the air, the aerodynamic noise.

In flight, the aerodynamic noise gradually increases in influence until, at speeds in excess of 400 knots, it is the principal contributor. The jet engine produces a peculiar type of noise whose frequency spread begins at the low end of the scale and goes very high into the ultrasonic range (well above 20,000 cycles per sec.). Sound spectra are of the continuous type, generally known as white noise because of the analogy to white light, with a wide plateau that begins at about 100 cycles per sec., runs more or less flatly toward 10,000 cycles per sec., and then begins to drop. There are a few peaks in the ultrasonic range which are not heard in flight because of masking by the slipstream. The similarity between the curves of engine noise and aerodynamic noise is marked. Both are white noise. In the future, we do not expect any principal changes to occur in such spectra as more powerful thrust is developed, only an elevation in the plateau level as intensity is increased. The noise produced by the more conventional propeller-driven reciprocating-engine aircraft (including the helicopter) is commonly called a discontinuous line-type spectrum. Both spectra are typified in Fig. 1. The energy content of the white or continuous spectrum noise is evenly distributed over its plateau, while it is peaked at a few points in the line-spectrum noise. For this reason, the total energy output of a white noise is considerably greater than the curve would indicate, while the energy content of a line-spectrum noise is close to its highest peak.

From the general laws on forced vibrations, it is known that the transmission efficiency of energy suffers with increasing frequency. Also, as the frequency increases, deflection, dispersion, and absorption of the energy in a traveling wave front occur at a higher rate because the wave length in the dimension of an obstacle in its path approaches or exceeds a 1:1 ratio. (A 20-m. wave at 16 cycles per sec. would not be blocked by an object as large as an office desk, while a wave of 1 cm. at 30,000 cycles per sec. would find the desk an impossible barrier.) One has but to recall the hollow quality of any sound in a fog to realize that the high-frequency components are quickly absorbed and that only the low-frequency elements travel any distance. This is the reason that shielding against high-frequency sound, including ultrasonics, is easily accomplished.

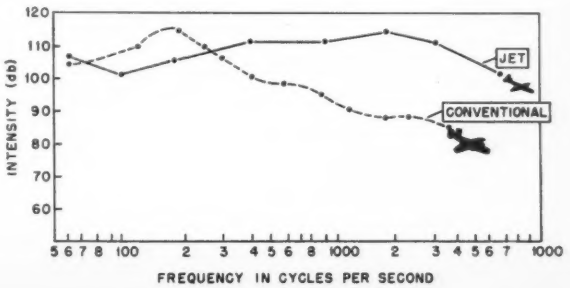

Fig. 1 Aircraft noise spectra.

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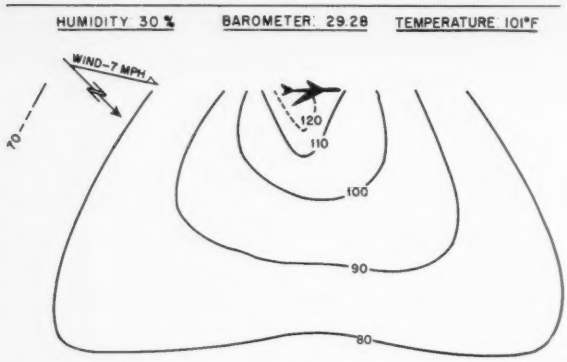

FIG. 2. Sound fields around a B-47 (modified from Sound Survey Report, Hq., S.A.C. August 13, 1951).

It is inconceivable that the jet-type transport of the future will not be pressurized as are the service jets of today. A pressure-containing cabin is a sealed cabin. This sealed fuselage will give good shielding against high frequencies, thus offering poor transmission to the interior. In addition, the conductance of ultrasonics in air is so poor that only a negligible quantity will reach the receptor. Even by solid conduction, as leaning against the wall or any solid structure, we find a low transmission efficiency because no true solid contact is established since several boundary or surface layers will always intervene (textiles, skin, muscles, etc.).

We can expect the sound level within a jet-type aircraft to be pleasantly low with little expenditure in material and weight because:

(1) Shielding reduces the high-frequency component in a continuous-spectrum noise and therefore greatly reduces the total energy transmission into the cabin.

(2) The low-frequency element that remains does not carry the excessive peaks of the conventional aircraft noise.

However, it is important to remember that shielding is effective only when a good seal is maintained. A large leak or explosive decompressive loss of a large window might allow entry of much sonic energy, as well as set up another source of vibration by acting as a venturi.

The propagation of sound outside the aircraft—that is, on the ground—is another story and not such a pleasant one. This propagation is subject to large variations. Among these variants are the material and absorption characteristics of the surrounding structures (hangars, ramps, aprons, sodded and decorative areas, etc.) and physical characteristics of the atmosphere which change air density per unit volume such as temperature, pressure, moisture content, wind direction, and velocity. Since these factors vary constantly, measurement of precise equal intensity distribution curves has little practical application for the medical man. The ranges between the minimum and maximum on a long-time observation basis are a more useful way of determining the sound pressure values at any given point around an airplane. Application of the square of the distance law for sound energy reduction gives approximate mean values at least at short distances for such ranges. It is difficult to predict precise sound intensity levels at a given point on an airport; changes of from 20 to 25 db. from the mean values will be found on repeated measurements. It is more useful, from the safety standpoint, to look for a combination of the worst possible circumstances (hot, humid air of high wind velocity blowing directly from the aircraft toward the observation point) and then to make the measurements. The service aircraft most likely to be a source of difficulty in military aviation and a problem in commercial flying (it to some extent will probably resemble the future jet transport) is the B-47 Stratojet bomber. One such measurement of equal intensity levels around such an aircraft is shown in Fig. 2. Under the conditions shown, maximum intensities were found to extend along radial lines at an angle of 45° to the longitudinal axis. The 80-db. level was found to be at 2,000 ft. from the airplane, the 90-db. level at 1,200 ft.

Effects of Exposure to High-Intensity Jet-Type Noise

Communications systems aloft are well protected during flight by the shielding offered by "buttoned up" cabins. It is not anticipated that air crews will have much difficulty in aural communication because of noise masking. An excellent signal-to-noise ratio can be obtained easily within the limits of the gain controls on modern receivers.

Much more attention will have to be directed toward ground location of radio facilities. Structural and spatial isolation from aircraft engines will be vitally necessary in order to maintain adequate signal-to-noise ratios at which radio communications can be carried on easily for the utmost safety of air operations.

The greatest shift of attention for medical responsibility from present-day habits will be an increasing concern for the ground maintenance worker. He is the individual who must work hard and efficiently and carry on communications with others, all the while being bathed by high-intensity sound fields for appreciable periods of time. In the normal individual, long-time exposure to intensity levels below 90–95 db. is generally considered to be safe. At intensities above this level, an injury known by the term "acoustic trauma" may occur. The degree of drainage depends both upon the intensity level and the duration of exposure. Generally, after a single mild exposure, the changes in hearing are completely reversible, while after a single severe or after repeated exposures a cumulative effect (permanent loss) will remain. For the foregoing reason, the degree of permanent loss depends on the time interval (rest time) between exposures, in addition to the intensity level and the exposure time.

From both human observation and animal experimentation, it has been found that the continuous-spectrum noise introduces more damage than a line-spectrum noise of equal intensity.[1] This evidence indi-

cates that the problem of deafness will be vastly greater as a general turnover to jet propulsion occurs. In addition to the direct liability for the individual worker by the Air Force or the carrier as his employer under Workmen's Compensation laws and applicable retirement laws, this means a more rapid labor turnover in a highly specialized field. As a direct consequence, there is introduced the even more hidden or indirect liability caused by the cumulative drop in maintenance efficiency affecting scheduling, hours of aircraft utilization, and safety in flight. At present, labor maintenance hours on jet engines are much greater than on conventional type, although time between engine changes is rapidly being extended. It is not inconceivable that more expert mechanics will still be required to maintain a jet transport or fighter fleet than an equal number of the conventional-type aircraft. In addition to the specific effect on the ear (acoustic trauma), aircraft noise has other general effects on individuals which increase irritability and lower personal efficiency. Jet noise has been found to be outstanding by many workers as a producer of these general effects.

There are two possible methods of getting maximum working efficiency and a reduction in liability. These are by selection of the proper personnel and by protection of the individual worker. There is certainly such a thing as individual susceptibility to noise. Preemployment testing of all workers who will be in high-intensity sound fields is mandatory in order to determine this individual susceptibility. Hearing efficiency in noise is only secondary to susceptibility as a determinant factor of employment. There are skilled individuals with impaired hearing for quiet and no apparent susceptibility to noise who do have a high hearing efficiency in noise and are therefore acceptable for employment from both standpoints.

Much work has been devoted to individual protective devices, and excellent ones have been developed. These include ear defenders (both insert and cup-type) and snug-fitting, padded helmets. These devices have been found to be most efficient when properly fitted, in spite of the fact that in the present models a certain element of inconvenience and discomfort from prolonged use is still present. In contrast to popular opinion, the wearing of such devices does not decrease hearing efficiency in noise, but a more favorable signal-to-noise ratio may be obtained by depressing the masking levels of noise. The medical department in both military and civilian circumstances has a great responsibility for the proper fitting of recommended devices and indoctrinating the wearer in the uses and advantages to be gained by wearing them, as well as the dangers of discarding them. There is quite a change in the aural cues a mechanic receives while wearing earplugs. This will not bother the new man, who will wear his ear defenders from the beginning, but the extremely experienced worker will have to retrain his ear until the new cues are established.

In addition to reducing noise intensity levels by wearing protective devices, it is possible to reduce the incidence of acoustic trauma by considering the time element of exposure to noise. A compromise between exposure periods and breaks in a quiet area must be worked out on a short as well as long-time basis. This means that multiple breaks must be given during the day and a transfer made to a quieter working area, after several months of exposure, for a period of several days to weeks. On the long-time basis, such a practice will give a greater overall level of efficiency and maintenance of aircraft.

It will be extremely important to institute an automatic system of checking maintenance workers on the overall hearing picture of each individual. This periodic check will give a basis for advising on rest periods, both in frequency and duration, and to see whether individual protective devices have been used as recommended.

Much more thought and care will be required in airport layout. It will be rather ridiculous to span the continent in 6 hours and then to hold it on the range leg in a stack at the end of the flight for another 6 hours. In addition, the higher fuel consumption of the jet will probably render such a procedure impossible. The most obvious solution is to construct jet ports that will handle this long-range type of transport exclusively and to restrict conventional aircraft traffic to its own airports. It would be vastly less expensive to place these new landing fields in the more remote regions adjacent to large cities. For additional liability protection, a clear zone of 3 miles around such a base should be created, and no one but employees and users of jet services should be allowed in the area. Happily, such a spacing would provide adequate protection against noise for adjacent habitations at no extra cost. The present airport buildings and terminals in most cases do not offer enough acoustic protection, and additional soundproofing and sealing will be necessary. Preflight, test, and work areas should be as far away from these structures as possible. Safety criteria have been established for sound levels in different areas, depending upon the use of the area. As mentioned before, sound levels in the audible range should never exceed 90–95 db. and should be kept below 85 db. in control observation rooms. Sound levels in areas of transient occupancy adjacent to test installations should never exceed 100 db. The criterion for easy conversation with a loud voice at 6 ft. is a maximum of 72 db. Noise outside open office windows and areas for sleep and rest (hospitals, homes, etc.) have lower criteria still.[2] As shown by Fig. 3, we now know the level is dependent upon frequency distribution, the lower levels being required in the higher frequencies. It is suggested that consideration be given in commercial aviation to loading and sealing the aircraft and then towing it away to run-up areas at the end of the strip. After turning off the runway on landing, the engine should probably be cut and the aircraft towed to the debarking ramp. Additional acoustic protection will be offered

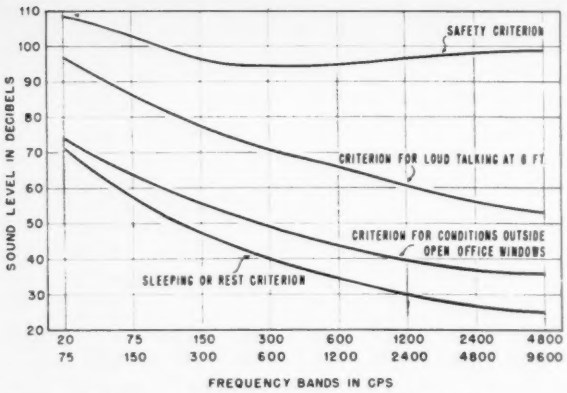

FIG. 3. Noise level criteria (modified from Sound Survey Report, Hq., S.A.C. August 13, 1951).

if loadings are not done while landings are being made. Acoustic barriers can be erected by placing hangers and other buildings between terminals and occupied areas and the landing strip. Earthen mounds and underground construction are quite practicable in protection against noise.

Acoustically protected test cells are now being engineered which will aid both the worker and those in the area. Remote control is being use :much as possible. Work is being done on concrete muffling devices to test engines while still in the air frame.

In order to overcome the long slow surface trip from the commercial jet port to the nearby city, a large helicopter can be used as a vertical low-level and very rapid lift. A passenger can be landed directly downtown from a distant jet port more rapidly than he can be driven in from the average airport today. Sound problems of this type of transport will be negligible for the occupants; for the people on the ground directly beneath, it will be extremely noisy. Perhaps slum areas that now exist in all of our major cities can be cleared for the location of helicopter landing areas and garages.

CONCLUSION

In conclusion, it is felt that from the standpoint of acoustic trauma, jet noise presents a much greater problem than reciprocating-engine aircraft noise. These problems are not insurmountable but can be handled if adequate advance preparation is made. The shift in medical emphasis today is toward selection and protection of the ground maintenance worker. Consideration of acoustical protection must be an important point in new construction. The personal equipment available today is fairly adequate but can certainly stand improvement. Here the emphatic need is for the thorough indoctrination of the individual worker. Air Force experience in handling large jet aircraft, although still limited, shows definitely that the airport of today is totally inadequate from a construction standpoint in offering suitable acoustic protection.

The sound fields we are now approaching appear to be far above the levels of safety and human tolerance. This applies particularly to Air Force bases and Navy carriers. It is to be hoped that, confronted by this challenge, engineers will approach the problem of noise abatement at the source—the only practicable method left to the future for human safety.

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Physiological Aspects of Prolonged Flight at High Altitudes and Survival in Emergencies

(*Concluded from page 60*)

civil and military aircraft; in others, radically different approaches must be taken. It is certain that in the aviation of coming years the human factor will continue to call for the utmost ingenuity and resourcefulness on the part of the aeronautical engineer and his medical advisers.

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Aeromedical Problems for Nuclear-Propelled Aircraft

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Introduction

Feasibility of peacetime uses for atomic power has been argued for several years. If one accepts the military need to fly half way around the world and return nonstop, utilization of nuclear fuel becomes realistic. Nuclear propulsion for aircraft presents many engineering and design problems. However, careful evaluation also reveals a series of medical problems resulting from the power plant, or more specifically from the nuclear radiations associated with the operations of the power plant. What are the restrictions to air-crew members from such an aircraft? What amount of radiation can an operational air crew accept? What are the effects of acute exposures to ionizing radiation? Is there a degree of sensitivity among individuals to radiation? Is there a specific psychological problem to selection relative to this radiation exposure? These questions and many others have initiated a widespread biological research program associated with nuclear propulsion.

To argue the feasibility of atomic power on the basis of 1 lb. of uranium releasing energy equivalent to 1,500 tons of coal may be somewhat naive, although the Cowles Commission on the Economics of Atomic Power did not rule it out. To consider the oil, gas, and coal reserves and their geographical location with reference to countries that are "energy-poor," yet industrially potential, makes the problem more realistic. Finally, to consider the possible need to fly half way around the world and return nonstop becomes a down-to-earth reality. The Air Force and the Navy are not only taking an optimistic view toward nuclear-powered aircraft, submarine, and surface craft, they are actually studying specific problems associated with nuclear propulsion. To gain an insight into these problems, let us first discuss the power source—a pile.

The Power Source

Fundamental to the nuclear reactor or pile is the fission process and the chain reaction. This fission process in certain materials such as U^{235} or Pu^{239} splits the elements into two fissions products, releasing tremendous quantities of heat and potential motion. If this heat is taken up by a liquid and put to work in generating steam, we have a conventional turbine-type system. This could be one type of a nuclear plane. To build such a plane, certain engineering problems arise: (1) developing an operable engine system, adaptable aerodynamically; (2) engineering a safe system for the release of energy at a controllable rate; (3) improvising equipment for converting heat energy into work energy to run the propulsion system; and (4) adapting the pile to an air frame—then it is ready for flight. This seems to reduce itself to an engineering problem, but, unfortunately, this is not the complete picture.

Admittedly, a pile is possible—fission will sustain itself—and the possibility of an adaptable air frame is not remote.

The Medical Problem

The aviation industry, both civilian and military, can no longer function without cross-support from the doctors in aviation medicine. The history of aviation proves that one of the greatest limiting factors to faster and higher flying is the human body—and not engines and metallic alloys. Now, as never before, the response of man to the varying stresses of flight must be considered in any aircraft design and development. This is even more important in the nuclear craft than the futuristic supersonic craft being studied and tested. Will aircrew members impose restrictions on this craft? Most definitely yes. The problems begin with the elementary reaction of fission. The fission fragments formed are intensely radioactive and decay by a succession of particle emissions and conversions accompanied by gamma radiation. In addition to these forms of radioactivity released by the fission fragments, the act of fission itself releases high-energy gamma radiation. Further, to propagate fission requires neutrons, which in turn become radiation hazards either as stray neutrons or by inducing artificial activity into previously stable components of the nuclear plane. These radiations of varying energy can and do penetrate matter; they can penetrate the human body without being sensed. By a process of ionization they attack living cells and can produce serious illness, and even death, over a variable period from days to years. Therefore, over and above all the current known stresses imposed by high-flying supersonic aircraft, the human body is required to accommodate to one more stress—biological and, yes, psychological stress—radiation.

The common denominator to radiation protection is shielding, but from here on the engineer and doctor must give and take. The engineer requires a minimum of shielding; whereas, the doctor would like to have a maximum amount. Therefore the question is: How much shielding is necessary for absolute protection? Is this prohibitive, aerodynamically speaking? To reduce the radiation from the pile and observe our present

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tolerance of 0.05*r* per day or 0.3*r* per week, the shielding alone would be in the neighborhood of 50 tons. Naturally, with all the other structural and operational equipment necessary, this is not practical. Then what is the minimum amount of radiation which can escape the shield and still allow this power plant to fly? Is this amount of radiation greater than the maximum permissible exposure the human body can tolerate? If not, how often can the air-crew members be exposed to this allowable amount of radiation without detrimental effects? Extensive radiobiology researches, observations of radiation effects from the bombs of Hiroshima and Nagasaki, and accidental radiation exposures within the A.E.C. and the old Manhattan District have enabled the medical men in aviation medicine to supply the engineer with the following data. Air crews may accept an exposure of 25*r* per mission, and it is probable that eight missions can be carried out at weekly or longer intervals. More missions may be feasible, but personnel should be carefully checked before being permitted greater exposure than *200r total, 8 25r missions.* From these data, the engineer is designing the necessary shielding so progress in the air-frame design can proceed.

To complete our medical obligations, however, answers to the following questions should be obtained. What are the effects of acute and intermittent exposures to ionizing radiation? Is there a degree of sensitivity of individuals to radiation exposure? Is there a specific psychological problem of pilot selection relative to this specific stress or hazard—radiation exposure? It is gratifying to report that current projects at the U.S.A.F. School of Aviation Medicine and at other institutions are channeled to solutions of these problems. The fact that reactor and air-frame contracts have been assigned is a vote of confidence that a new era in aviation medicine has begun.

Vision at High Speed and Altitude

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Crash Protection in Air Transports

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A WELL-EXECUTED EMERGENCY DITCHING in calm water, where both the speed and the angle of impingement of the aircraft are kept low, will result in a deceleration of less than 10g's, entirely harmless to the well-braced occupants. In a recent accident, a jet bomber nosed in from low altitude at more than 500 m.p.h. Only 19,000 lbs. of fragments, none bigger than one man could carry, were all that could be found of the 193,000-lb. aircraft. The unidentifiable remains of the three crew members totaled 9½ lbs. Between these extremes are the majority of aircraft crashes, in which, excluding the effects of fire, survivors diminish in number toward the vanishing point as the estimated decelerative forces approach 50g's. Yet, as will be revealed presently, abrupt decelerations of 50g's can be sustained without loss of consciousness or injury, and impacts of more than 100g's can be survived. This becomes increasingly important as airplanes fly faster and inevitably crash harder.

Based on observations of accidents and on experimental evidence, it can be assumed that the dissipation of kinetic energy in an aircraft crash occurs in ½ sec. or less. Crash forces are determined by the mass and velocity of the aircraft; their direction is a resultant of the horizontal and vertical components of its angle of impingement against the terrain. The subsequent irregular pattern of deceleration corresponds to the diminishing momentum of the aircraft as its structure fails and the terrain resists its motion by collision and friction. Decelerative forces can be analyzed by determining the following factors: (1) rate of change of deceleration, (2) peak or plateau deceleration, (3) direction of the forces, (4) area of distribution, (5) time-displacement, and (6) duration.

The forces transmitted to occupants of the aircraft are determined by: (1) their attenuation and absorption by structures intervening between the occupant and areas of the aircraft impinging against the ground; (2) distance and direction of displacement of the occupant; (3) area, configuration, and resistance of objects against which the occupant is decelerated; (4) attenuation and absorption of force by the body of the occupant; (5) rate of application of the forces; (6) frequency characteristics; and (7) duration.

The problem of evaluating the effect of these factors requires controlled experimental exposure of human, animal, and anthropomorphic dummy subjects to crash-type decelerations. Progressively augmented combinations of these variables will determine tolerance and survival limits. Simultaneously, the efficacy of various restraint configurations and development of basic principles of crash protection can be explored.

Progress in this field has been limited by the formidable mechanical problems, the difficulties of developing maintaining and operating experimental apparatus subjected to high impact forces, and the hazardous nature of the experiments for human subjects.

In 1946, a competitive design study resulted in the development of a machine to produce abrupt linear decelerations similar to those encountered in crashes, ditchings, parachute opening shocks, and rocket-power escape capsules.

The device consisted of a 1,500-lb. tubular-steel sled slipper mounted on a 2,000-ft. standard gage track and propelled by one to four solid-fuel rockets, each having 1,000 lbs. thrust for 5-sec. duration. After accelerating to the required velocity, the sled entered a section of fixed mechanical friction brakes located between the rails in a 50-ft. length at a point 1,250 ft. from the beginning of the track. These brakes were preset in a predetermined sequence and were tripped by cams on the sled. Two parallel keels beneath the chassis were clasped by the closing brakes with an action similar to pulling a knife blade through a vise, causing the sled to lose momentum in a controlled reproducible pattern.

The controlled range of operation was from 10*g* to 60*g* by 5*g* increments, with durations of 0.08 to 0.42 sec., at rates of change of acceleration from 280–3,400*g* per sec. The sled could be stopped in less than 20 ft. from a velocity of 180 m.p.h., with peak decelerations exceeding 100g's. Dummy, chimpanzee, or human subjects, restrained in the configuration and plane of orientation required for a given experiment, were suitably instrumented with accelerometers and strain gages recording through telemetering and were photographed during deceleration by high-speed motion pictures and ribbon-frame cameras.

Between April, 1947, and June, 1951, the linear decelerator was operated by its designers, Northrop Aircraft, Inc., for the Aero Medical Laboratory of Wright Air Development Center at Edwards Flight Test Center, where a suitable track was available. Seventy-two tests with parachute dummies, 73 human experiments, and 88 experiments with chimpanzees were accomplished.

Between June, 1951, and November, 1952, another decelerator was devised and put to use at Edwards Flight Test Center. This consisted of a monorail from which a welded-steel carriage was suspended. Propulsion along the 30-ft. greased monorail was obtained by a

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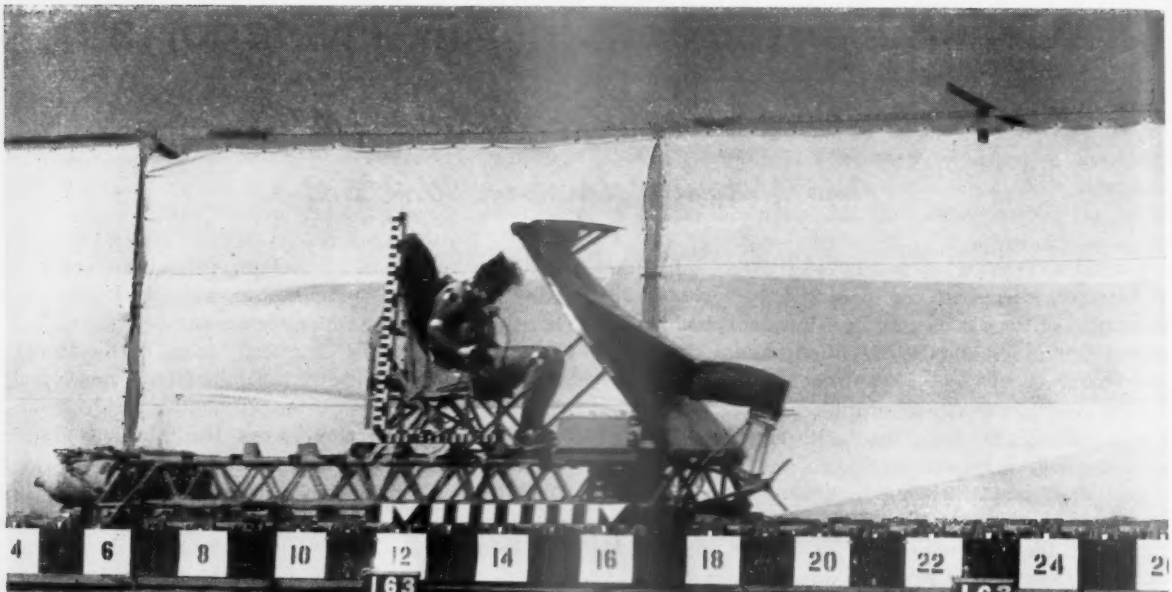
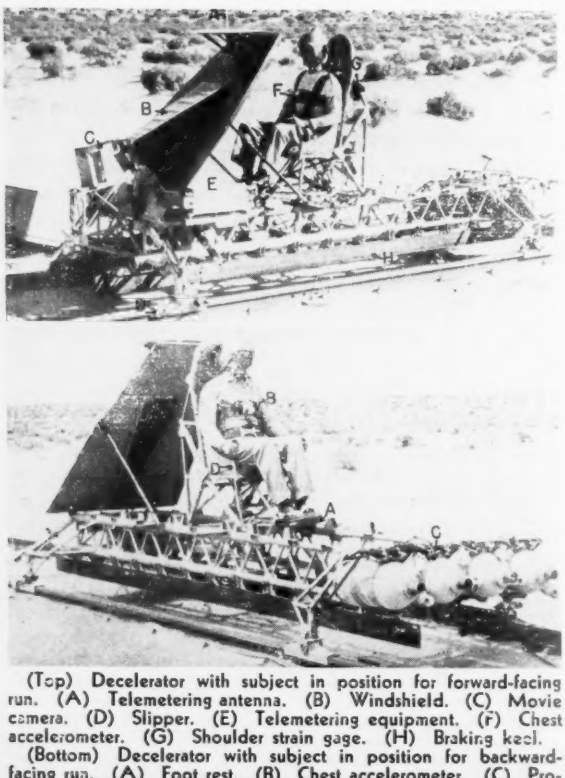


Run No. 163; from 88.6 m.p.h. to a stop in 18 ft.



(Top) Decelerator with subject in position for forward-facing run. (A) Telemetering antenna. (B) Windshield. (C) Movie camera. (D) Slipper. (E) Telemetering equipment. (F) Chest accelerometer. (G) Shoulder strain gage. (H) Braking keel.
(Bottom) Decelerator with subject in position for backward-facing run. (A) Foot rest. (B) Chest accelerometer. (C) Propellant rockets. (D) Vertical hand hold.

standard ejection seat catapult. The charge could be varied to permit a velocity range from 15 to 47 ft. per sec. The carriage decelerated by impinging against a lead cone on a frame at the end of the rail. Different sizes and shapes of lead cones provided corresponding variations in the deceleration pattern from 30*g* to more than 200*g* at rates of onset varying from 1,500–40,000*g* per sec. and with durations of $^{1}/_{100}$ to $^{8}/_{100}$ sec.

Fifty-one experiments were accomplished with this device by Winquist and Stumm, using as subjects anesthetized hogs varying in weight from 70 to 134 lbs. Instrumentation included strain gages on harness components, accelerometers bolted to the carriage, and accelerometers imbedded surgically in the lumbar back region and in some cases over the sternum or abdomen. High-speed motion pictures, X-rays of the vertebral column, and autopsies, either immediately or within 10 days following survival were accomplished on all subjects.

In all, seven body orientations were used in these experiments. A summary of the tolerance and uninjured survival limits obtained in these experiments is shown. Human tolerance to decelerative forces is lowest in the buttocks first or upward seat ejection position. Experiments with hog subjects in this position caused no injury at 79*g*'s, but resulted in mid-thoracic vertebral fractures at 86*g*'s.

The effect of the third derivative of motion, designated as the rate of change of deceleration, on tolerance to abrupt decelerations, was first investigated by Bierman in 1945 during his tour of duty with the Navy. He attempted to modify the rate of onset applied by a

weighted harness dropped on a human volunteer subject by making the webbing out of undrawn nylon, which absorbs energy by permanent deformation of the fibers. This idea never went beyond the experimental stage because undrawn nylon is unstable. Its draw properties are unreliable, and after threefold lengthening of the straps, a crash harness could not hold the pilot against collision with the crowded interior of a cockpit.

The effects of the rates of change of deceleration are suggested by the diagram of slopes and peaks. Run No. 133, with a rate of change of deceleration of 1,370*g* per sec., and a peak of 38.6*g* resulted in the most severe transient physiological effects that were encountered in the entire series of human experiments. The subject fainted twice immediately following the run and manifested many subjective signs of acute distress, complaining of intense muscle soreness for several days. In contrast, the very same plateau of 38.6*g*'s was applied to another human subject at a rate of change of 331*g* per sec. with no subjective or physiological changes other than the effects of excitement and exertion. In most subjects sustaining decelerations of more than 30*g*'s at more than a 1,000*g* per sec. rate of onset, pallor, drop in blood pressure, increased pulse rate, and perspiration were noted.

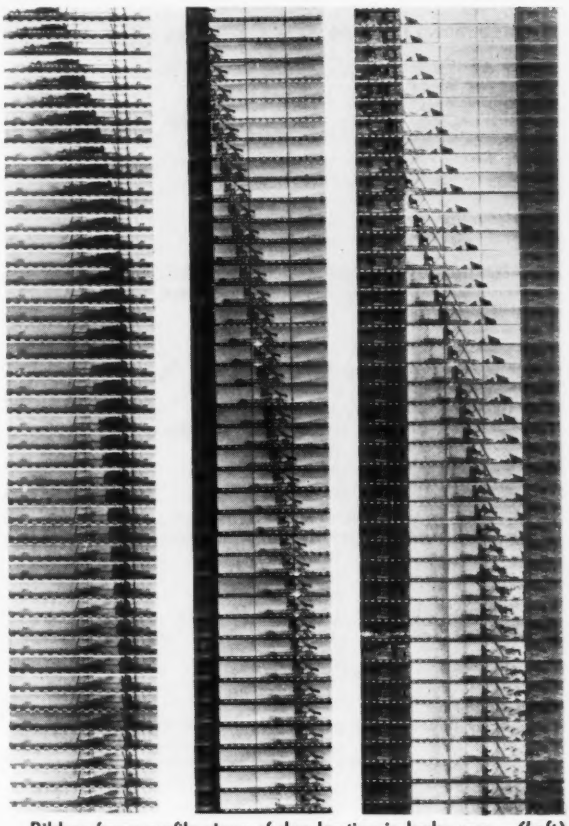
In one case where the rate of change of deceleration was kept below 500*g* per sec., a peak of 45.4*g* was applied to the subject without producing these manifestations of shock.

In the case of the monorail deceleration experiments with hog subjects, exposure to abrupt impacts in the rear-facing seated position with the back applied to a firm surface of "Styrofoam" had an injury threshold of 80*g*, as compared to an injury threshold of 125*g* in the forward-facing seated position restrained by nylon webbing of 35 per cent elasticity. This difference reflects the attenuation of the rate of change of deceleration due to the elasticity of the nylon webbing, demonstrated by high-speed motion pictures.

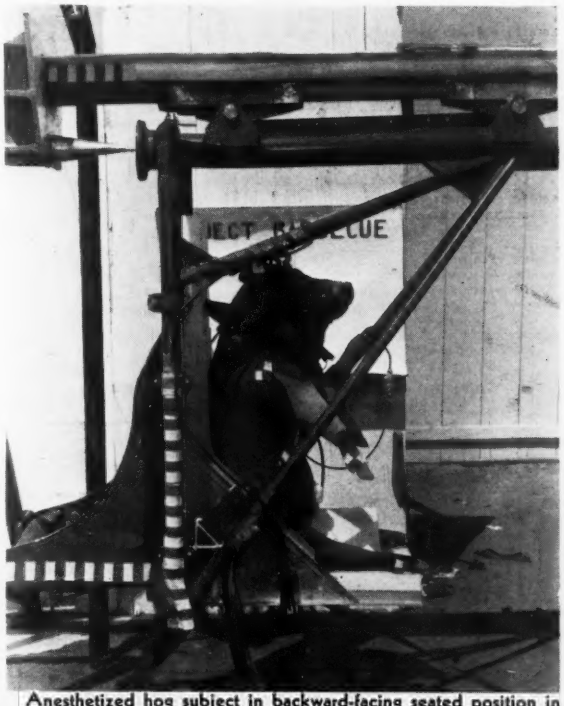
It becomes evident from the high levels of tolerance found with human volunteers and the extremely high forces survived without injury by animal subjects, chosen for their approximation of human dimensions and weights, that protection of human occupants of aircraft from abrupt crash forces is determined not by human limitations but by the dynamic stress limitations of aircraft.

The foremost hazard to aircraft occupants following a crash is fire. Adequate crash protection might enable uninjured survivors to get out more quickly, but it is futile to be saved from concussion only to be cremated. The N.A.C.A. and various other agencies are finding many answers to the fire problem, particularly in the prevention of instantaneous flash fires following a crash, so that passengers will have a little more time in which to escape from the wreckage, provided they have survived the crash forces.

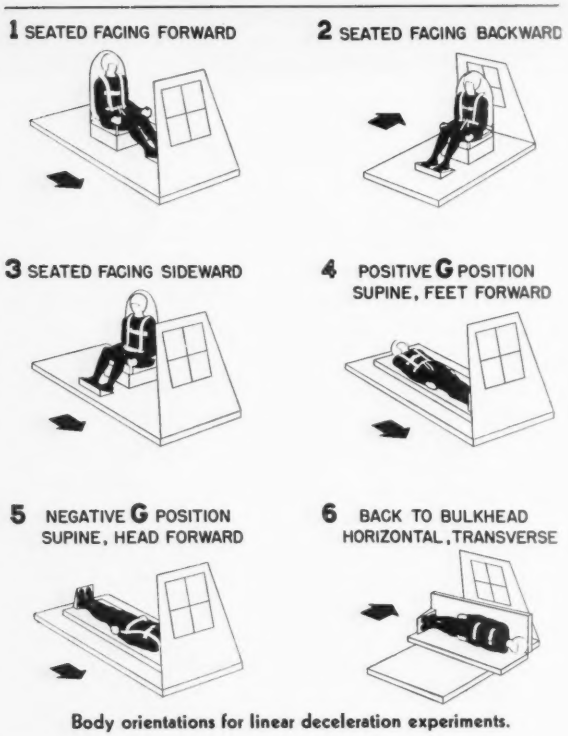
Most air transports are equipped with forward-facing seats stressed to about 6–9*g* and a 2-in. width lap belt



Ribbon frame profile views of deceleration in brake area. *(Left)* Anesthetized chimpanzee, supine, head first going from 169 m.p.h. to a stop in 20 ft. *(Center)* Human volunteer seated facing forward, going from 88.6 m.p.h. to a stop in 18 ft. *(Right)* Parachute dummy during failure of undrawn nylon harness.



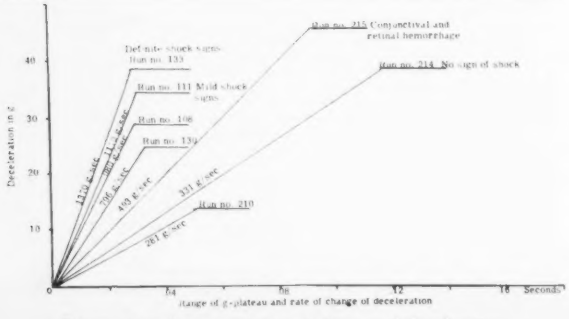
Anesthetized hog subject in backward-facing seated position in carriage of monorail decelerator. Note lead spike and impinging plate in *upper left*. Carriage is suspended from rail by two slippers, *upper center and right*.


1 SEATED FACING FORWARD
2 SEATED FACING BACKWARD
3 SEATED FACING SIDEWARD
4 POSITIVE G POSITION SUPINE, FEET FORWARD
5 NEGATIVE G POSITION SUPINE, HEAD FORWARD
6 BACK TO BULKHEAD HORIZONTAL, TRANSVERSE

Body orientations for linear deceleration experiments.

POSITION	PEAK "G"	RATE OF CHANGE g/sec	TOTAL DURATION SECONDS
1 SEATED FORWARD FACING			
a TOLERANCE (human)	10-46 6	280-1370	15-37
b SURVIVAL, UNINJURED			
(CHIMPANZEE)	9-100 0	210-3400	10-20
(HOG)	30-125 0	1500-15000	04-08
2 SEATED BACKWARD FACING			
a TOLERANCE (human)	10-35 0	500-1200	15-42
b SURVIVAL, UNINJURED			
(CHIMPANZEE)	20-100 0	870-3350	10-16
(HOG)	20-100 0	1500-15000	04-08
3 SEATED FACING SIDEWISE			
a TOLERANCE (Chimpanzee)	20-47 0	900-1200	12-17
4 SUPINE, FEET FIRST			
a TOLERANCE (Chimpanzee)	28-51 0	700-1000	13-20
5 SUPINE, HEAD FIRST			
a SURVIVAL, MINIMAL INJURY			
(CHIMPANZEE)	11-150 0	550-1450	08-35
6 SEATED, BUTTOCKS TO HEAD			
a TOLERANCE (human)	5-33 0	50-400	004-03

Tolerance and survival limits for linear deceleration.



Range of g-plateau and rate of change of deceleration.

of between 2,000 and 4,000 lbs. break strength. The lap belt alone, used in the forward-facing seated position, can permit uninjured survival of exposure to decelerations up to 20*g* at a 1,000*g* per sec. rate of onset, and possibly of higher forces with some degree of injury, if the following conditions can be met:

(a) Belt, seat, and all attachments to seat and to aircraft floor are of 20*g* strength with adequate safety factor for brief overloads.

(*b*) A minimum clearance of 44 in. between seats is provided so that the passenger does not strike his head on the back of the seat in front of him.

(c) The 20*g* deceleration must be in the long axis of the cabin and free from violent gyrations and lateral or vertical components that might throw the passenger out of the belt loop or against arm rests.

(d) The belt must be tightened properly into the crease of the hips, leaving no slack to apply abrupt overloads to seat attachments.

For all of these conditions to be met simultaneously would indeed be fortuitous, even though 20*g* seats, lap belts, and attachments with adequate spacing between seats were provided. The tightness or looseness and the position of the lap belt are at the discretion of the passenger, as well as his attitude and posture in the seat.

The final requirement, of course, is that the passenger be a young athletic adult, preferably male. Pregnant women, infants, small children, the obese, the elderly and the infirm are not anatomically and physiologically adapted to such violent protection. How many *g*'s of deceleration would be required to snatch an infant from the arms of its mother as her torso and legs hinge on the safety belt and jack-knife forward? Suppose that a passenger in the rear of the transport fails to fasten his safety belt. He plunges into the back of the seat in front of him, which, loaded with the weight of two passengers, gives away and crashes into the next seat, starting a chain reaction of failures resembling the toppling of a row of dominoes.

What is the actual record of the safety belt and forward-facing seat, based on the analysis of transport crashes? In a recent review by Dr. Eugene F. DuBois, of Crash Injury Research, entitled "Safety Belts Are Not Dangerous," he reports that, over a 10-year period in which 858 crashes were investigated, no internal injuries in the area beneath the belt were found. Indeed, with 6.6*g* stressed seats and belts of 3,000 lbs. or less pull strength, why should any internal injuries be expected? Ruff and associates in Germany in 1941 were able to attain 18*g* in experiments with human subjects restrained by a lap belt, riding in a swing, snubbed by bungee shock absorbers, with only slight nausea and momentary distress. It is evident that in the 858 crashes reported by DuBois, all seats must have failed before reaching 18*g*'s. Experiments with anesthetized hogs restrained by a lap belt resulted in injuries at 53*g* deceleration.

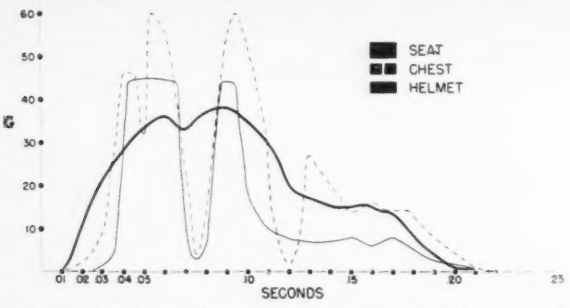
In a survey of 800 crash survivors by Cornell University's Crash Injury Research, 704, or 88 per cent,

Run No.	Subject	A Initial Velocity (ft/sec)	B Final Velocity (ft/sec)	C Velocity Change ft/sec	C Velocity Change mph	D Duration (Seconds)	E Equivalent Stopping Distance (Feet)	F Calculated Slope (G/sec)	G Calculated Plateau (G)	H Weight of Subject (pounds)	I Force G x H (pounds)	J Harness Area (sq. in)	K Harness Pressure (PSI)
		Configuration No. 1 Deceleration Distance, 47.1 feet Active Brake Units, 1,2, ----------12, 13, ----------23. 24.											
96	JPS	217	115	102	69.5	.30	12.6	1170	11.3	172	1940	137.5	14.1
101	JPS	No displacement record											
119	JPS	202.5	95	107.5	72.6	.33	15.6	1060	10.9	174	1893	217.5	8.7
120	DIM	No displacement record											
121	WAR	200.5	72	128.5	87.6	.37	20.5	575	11.9	152.5	1814	207.5	8.7
		Configuration No. 2 Deceleration Distance 39.4 feet Active Brake Units 1,2,3, ---------- 12, 13 14,----------23, 24											
94	JPS	216	128	88	61	.21	8.5	1055	15.0	172	2575	261	9.9
95	JFF	No displacement record											
97	WAR	226	149	77	52.3	.21	7.1	1079	15.0	155	2310	244.5	9.5
98	WAR	214	116.1	97.9	66.3	.21	11.0	1150	16.8	154	2586	207.5	12.5
102	RHA	216.2	121	95.2	65	.21	10.0	1165	16.7	170	2840	265.5	10.7
106	DIM	220	126	94	64.3	.21	9.0	1170	16.6	176	2920	271.0	10.8
117	RHA	220	145.5	74.5	50.7	.21	4.9	980	13.9	170	2366	204.0	11.6
118	RL	202	113.5	88.5	60.4	.22	10.6	923	14.3	177	2522	238.0	10.6
149	FMS	215.5	123	92.5	63.2	.235	16.5	970	17.5	197	3445	198.2	17.4
150	HG	223,5	141	82.5	56.3	.22	4.4	935	16.9	208	8500	198.7	17.6
164	WJAM	195	92	103	70	.22	15.2	940	15.0	(142+21)	2445	168.0	14.2
		Configuration No 3. Deceleration Distance 26.7 feet Active Brake Units, 1,2,3,4 ---------- 12,13,14,16											
99	JFF	216.2	129	90.2	1.5	.16	6.5	1101	21.2	149	3160	201.3	15.7
100	WAR	220	129.5	90.5	61.8	.16	6.0	1080	20.4	155	3225	244.5	13.2
142	WAR	222	135	87.0	59.4	.16	5.1	1150	21.2	155	3280	176.5	18.6
143	JFF	219	128	91.0	62.2	.16	6.2	1015	23.5	149	3500	170.3	20.6
146	WAR	220	131	89.0	60.8	.16	5.7	1022	23.3	155	3610	176.3	20.5
147	JFF	210	108	102	69.6	.175	7.8	1000	24.1	149	3590	170.3	21.2
148	WAR	No dis lacement record											
162	JPS	No displacement record											
163	Jrb	132	0	132	[illegible]	.23	18.5	894	32.0	(170+21)	6112	186.0	32.9
165	JPS	206	126	80	54.4	.17	5.3	934	18.0	(170+21)	3436	186.0	18.5
166	JPS	200	107	90	63.2	.175	8.0		19.4	170	3298	186.0	17.7
		Configuration to 4 Deceleration Distance 25.7 feet Active Brake Units, 1,2,3,4,5 ---------- 12,13,14											
103	JFF	224	140	84	57.3	.16	3.3	1110	25.8	155	4000	240.3	16.7
104	WAR	206.6	122.2	84.4	57.	.16	6.2	975	24.3	152	3695	207.5	17.8
105	RHA	No displacement record											
122	JFF	204	126	78	53.2	.16	5.6	980	25.0	152	3800	201.3	18.9
		Configuration No. 5 Deceleration Distance 24.6 feet Active Brake Units, 1.2.3.4.5.6 ---------- 12.13											
107	JFF	218	134	84	57.3	.16	3.2	946	27.0	149	4030	240.3	16.8
108	WAR	212	129	83	56.7	.15	4.0	980	28.9	153	4422	207.5	18.1
109	RHA	213	133	80	54.6	.155	2.4	990	28.2	170	4800	204.0	26.9
110	JPS	226	142	84	57.4	.15	2.0	1150	31.5	172.5	5490	217.5	25.2
111	JFF	211	104	107	73.0	.15	8.0	1170	34.6	152	5255	240.3	21.8
123	RHA	197.6	106	91.6	62.0	.16	7.7	910	26.5	170.5	4859	204.0	23.8
124	JPS	210	134	76	51.7	.16	3.2	900	26.7	174.5	4659	217.5	21.4
129	WAR	No displacement record											
130	JFF	201	124	77	52.5	.16	4.8	796	24.8	153	3791	240.3	15.8
		Backward Facing, Seated Position •											
113	WAR	206	90	116	78.1	.16	8.2	1156	35.0	152	5320	260	20.5
114	JFF	208	96	112	76.4	.16	9.2	1160	34.8	153	5324	252	21.1
		Configuration No. 6. Deceleration Distance 24.6 feet											
133	RL	213	87	126	86	.155	11.1	1370	38.6	177	6839	238	28.7
135	JPS	220	105.5	114.5	78.9	.16	7.7	1344	38.1	172	6553	217.5	30.2
		Configuration No. 7 Reduced Brake Pressure											
210	PWS	Deceleration Distance, 39.5 feet. 38 consecutive brakes at 150 to 200 p.s.i. closing pressure 210	116	94	64.2	.237	12.0	281	13.9	206	2864	280	10.2
211	JPS	Deceleration Distance, 34.4 feet 35 consecutive brakes at 200 to 250 p.s.i. closing pressure 218	123	95	64.8	.215	9.9	288	20.6	175	3604	217.5	16.6
212	PWS	Deceleration Distance, 34.3 feet 33 consecutive brakes at 250 to 300 p.s.i. closing pressure 210	89.5	120.5	82.2	.217	14.9	300	32.7	206	6738	280	24.1
213	JPS	Deceleration Distance, 36.4 35 consecutive brakes at 250 to 300 p.s.i. closing pressure 224	71.0	153	97.5	.250	18.7	314.5	36.5	175	6386	217.5	29.4
214	PWS	Deceleration Distance, 36.4 35 consecutive brakes at 300 to 350 p.s.i. closing pressure 222.5	41.0	1815	123.8	.283	21.8	331	38.62	206	7938	280	28.35
215	JPS	Deceleration Distance 31.6 feet 30 consecutive brakes at 350 to 400 p.s.i. closing pressure 226	50.2	1758	120.	.228	19.7	493.5	45.4	175	7942	217.5	36.5

A. Velocity at entry to brakes
B. Velocity at exit from brakes
C. Velocity change in miles per hour and feet per second
D. Duration of deceleration
E. Calculated equivalent stopping distance for the observed deceleration if final velocity were zero
F. Initial slope of deceleration-time curve calculated from displacement-time record.
G. Plateau of trapezoidal deceleration-time curve calculated from displacement-time record.
H. Weight in pounds of subject just prior to run.
I. The product of calculated plateau g-times the weight of t e subject , from columns F and G.
J. Measured area of harness webbing impinging on the subject in the forward seated position.
K. The force in column H, divided by the harness area column I, to give average harness pressure

• Measured back area of subject against seat.

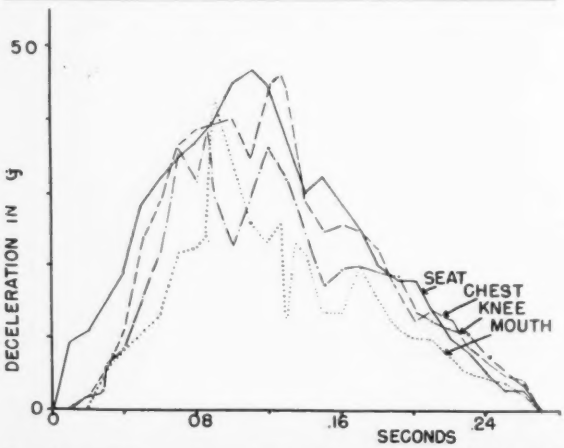
Analysis of time-displacement data for human subjects.



Experiment 113, accelerometer records. Human subject seated facing backward.

sustained head injuries; 641, or 80.1 per cent, sustained leg injuries; and 250, or 13 per cent, sustained injuries of the lumbar spine, abdomen, hips, pelvis, sacrum, and perineum. Much is made of the fact that injuries in the belt area, such as bruises, were sustained by 32 survivors, with only 23 showing evidences of intra-abdominal injury. The fact that the lap belt, submitted for use as a protective device, seldom produces injury is scarcely a cause for rejoicing. The obvious fact that 88 per cent of the survivors of 800 crashes received head injuries while depending on the lap belt alone for protection, not to mention the other less numerous varieties of injuries incurred, hardly recommends it as a safety device. Rather, it would seem that the lap belt is being endorsed as socially acceptable, so long as the passengers suffer broken necks and fractured skulls but are not afflicted by ruptured urinary bladders. Must the pile-up of seat and belt failure in a 120-m.p.h. crash at less than 20° angle of impingement be tolerated as an act of God and an acceptable risk of air travel, in the face of experimental proof that uninjured survival of the crash forces would be routine if protection were adequate? Statistics can become the most accurate possible way of missing the point.

Correct thinking on the subject of passenger safety would demand to know what is better than a lap belt in forward-facing seats. Stronger seats, stronger fittings, and the addition of shoulder straps would be an improvement but not an acceptable answer for passengers who might decide that air travel is unsafe if they were hog-tied for the ride.



Experiment 215, accelerometer records. Human subject seated facing forward.

The answer is in the use of high-strength backward-facing seats, for which the present lap belt is adequate restraint. In such seats, the reclining feature for the back can be retained, provided the pivot point is above the center of gravity of the occupant so that crash forces would return the back to the near vertical posture. Head rests should extend above the passengers' heads so that the roof is held away in case the aircraft overturns and caves in.

In the case of a 175-lb. occupant applying 300 sq.in. of back surface to a rear-facing seat during deceleration at 40*g*, the loading pressure will be 175 × (40/300) = 23.3 lbs. per sq.in. In contrast, consider the case of a 175-lb. occupant of a forward-facing seat restrained by a 2-in. width lap belt impinging approximately 20 in. of its length across the anterior aspect of his trunk. Against 40 sq.in. of belt surface, the occupant will sustain 87.5 lbs. per sq.in. of pressure at 20*g*; at 40*g* deceleration, 175 lbs. per sq.in. There is no question that 23.3 lbs. per sq.in. can be sustained against the back surface of the body; 26.7 lbs. per sq.in. has been sustained by a human subject on the decelerator without ill effects. For obvious reasons, no human subjects have been experimentally exposed to 175 lbs. per sq.in. against the abdomen, or even to 87.5 lbs. per sq.in.

A high-strength backward-facing seat that can be folded out of the way has been designed by the Aircraft Laboratory of Wright Air Development Center and is being installed in all aircraft of the Military Air Transport Service, beginning with the C-97's.

The British have installed high-strength backward-facing seats not only in R.A.F. transports but in some domestic air liners. It has been reported that more than 150 passengers have survived uninjured in about half a dozen crashes of aircraft with rear-facing seats. Cornell Crash Injury Research published a careful analysis of two R.A.F. crashes of aircraft with rear-facing seats one of a four-engined transport in December, 1950, and the other of a twin-engined plane in February, 1951, in which 39 survived, all of them occupants of rear-facing seats.

With respect to the acceptability of backward-facing seats to air-transport passengers, the following direct quotations are made from the report (published in April, 1947) of a staff study conducted by Traffic Division of the Air Transport Command, U.S.A.F.:

"The Traffic Division, Air Transport Command, unwilling to accept as dogma a statement of passenger reaction based upon travel in railroad day coaches, particularly in the face of the great safety gain possible through the adoption of such a plan, received permission from the Commanding General to conduct an investigation into the passengers' real reactions to such a proposal. Accordingly, two aircraft of the transcontinental 'Statesman' flight, operated by the Eastern Pacific Wing, Pacific Division, were prepared with all seats facing aft. Upon being placed into service, each pas-

senger boarding a reverse seat aircraft was given a folder that explained, in language easily understood by the layman, the advantages to be gained from riding in this unorthodox position and the reasons behind the test. He was asked to comment on his reactions at take-off, in flight, and upon landing. This test was continued until a total of 1,020 questionnaires were filled out by passengers from all walks of life, military and civilian, male and female."

"Astonishingly enough, the passengers, given a reasonable explanation of the change, expressed themselves as overwhelmingly in favor of the change and indicated no discomfort or adverse reaction to this type of seating, except in a very small percentage of cases.

"It was found that, because of the lack of any sensation of forward motion once the airplane was air-borne, the instances of air sickness or other undesirable effects common to railroad trains or other surface vehicles was in no way accentuated.

"It was recognized during this study that the present type of aircraft seat, because of its design, would provide very little additional safety, since the seat could be expected to give way under the stress encountered in emergency landings. This, however, is an engineering problem susceptible to ready solution, and at the request of this Headquarters, it is now in the process of investigation and research at Wright Field, where deceleration test equipment has been procured to conduct the experiment. These tests were scheduled to begin in April of this year [1947].

"The investigation into passenger reaction conducted by this Command would indicate that with proper education the traveling public may be expected to concur. In fact, it is believed that measures of this type taken by the operators of transport aircraft, and properly explained to those who ride them as passengers, serve rather to increase the passenger's sense of security and may well constitute an incentive to the further use of air transportation. The traveling public has never refused to ride trains because of the installation of safety devices such as automatic block signals, steel cars, fire extinguishers, etc., nor have they boycotted the steamship lines because of the presence of life boats and frequent 'abandon ship' drills. The intelligent passenger cannot fail to appreciate the carrier, who, recognizing certain dangers inherent in the method of transportation used, takes every precaution within his power to assure his safe arrival.

"It must be emphasized that all statistics indicate that airplanes will continue to undergo crash landings. The weight of opinion would appear to support the theory that most, if not all, passengers involved in this type of accident could survive the impact and that chances of survival in fires resulting from crash landings would be substantially increased. If the rearward-seating principle is disregarded, these passengers will die. It may well be economically unfeasible to modify present aircraft, but when lives are balanced against dollars, there can be no excuse to continue designing new aircraft without embodying this safety factor."

QUESTION		ENLISTED MALE	OFFICER MALE	CIVILIAN MALE	ENLISTED FEMALE	OFFICER FEMALE	CIVILIAN FEMALE	UNKNOWN	TOTAL
IS THIS YOUR	YES	252	274	114	6	11	15	163	835
FIRST BACKWARD	NO	46	78	19	1	–	–	41	185
AIR RIDE?	NO COMMENT	–	–	–	–	–	–	–	–
WAS YOUR TAKE –	YES	293	327	70	7	11	15	195	918
OFF SATISFACTORY?	NO	4	8	2	–	–	–	2	16
	NO COMMENT	1	17	61	–	–	–	7	86
IS YOUR VISIBILITY	YES	240	252	90	5	7	12	186	792
IMPROVED BY THIS	NO	47	92	36	2	4	3	7	191
ARRANGEMENT?	NO COMMENT	11	8	7	–	–	–	11	37
WAS YOUR LANDING	YES	277	331	122	7	11	12	191	951
SATISFACTORY?	NO	12	16	3	–	–	3	8	42
	NO COMMENT	9	5	8	–	–	–	5	27
CONSIDERING SAFETY	YES	282	333	128	6	11	14	185	959
DO YOU FAVOR	NO	12	17	4	1	–	1	10	45
THIS IDEA?	NO COMMENT	4	2	1	–	–	–	9	16
SHOULD WE REVERSE	YES	261	297	121	6	9	14	188	896
ALL PASSENGER	NO	33	35	8	1	2	1	5	85
SEATS?	NO COMMENT	4	20	4	–	–	–	11	39
		298	352	133	7	11	15	204	1020

Passenger opinions of backward seating. A.T.C. Staff Report, April, 1947.

It is apparent that, with equal strength of structure, the rear-facing seats still offer more crash safety than the forward-facing seats. The problems of turning the seats around and attaching them securely have already been solved by Military Air Transport Service and by the British domestic air lines. What the British can do, the United States can do.

The next 10 years of aviation progress will not wait for another 700 broken heads to be added to the statistics of lucky survivors. Things are getting worse, not better. Faster aircraft will crash harder, and their occupants will be exposed to higher impacts in accidents.

Positive progress in the next 10 years is essential in the development of crash protection, based on experimental information already available. Passengers are at least entitled to all the safety that can be built into air transports without compromising performance.

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In order that the *1953–1954 I.A.S. Roster of Members* be as complete and accurate as possible, a last call is being issued for required data concerning present employment and titles and preferred mailing addresses of I.A.S. members.

Some members have failed to send in their completed roster data cards. Make sure that your data card is filed immediately. This is your last opportunity to be correctly listed in the *1953–1954 I.A.S. Roster*.

Impact of Modern Aviation on Health

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U.S.A.F. School of Aviation Medicine

Introduction

The title of this paper is admittedly rather broad, and therefore it seems logical to arrange this subject into three categories: (1) health hazards in aircraft operation, which includes the problems of noise, crash injury, hypoxia, and radiation; (2) health hazards in air travel, and (3) some improvements in health for which aviation deserves some measure of credit.

Health Hazards in Aircraft Operation

I should like to mention a few of the hazards that are closely related to industrial medicine and toxicology and which are encountered in aircraft operation.

We need not wait for NEPA to encounter radiation hazards. Certain electronic tubes already in use contain radioactive components and present hazards in storage and handling. Radioactive tracers are finding increasing application in industrial research on aircraft engines and equipment.

Carbon monoxide presents a peculiar hazard in operation of aircraft, because this gas combines with hemoglobin in the blood and impairs its oxygen-carrying capacity. A concentration of 100 parts per million, which is permissible on the ground, is dangerous in flight. If such a concentration, because of leaks in the heating system, were present in a pressurized cabin with a pressure-altitude of 8,000 ft., the occupants would be subjected to the same degree of oxygen-deprivation as if they were actually at about 11,000 ft.

Fire extinguishants present some peculiar problems in aircraft operation. In many types of airplanes, fires in certain stations will actuate an automatic built-in extinguishing system. The fire is frequently controlled, and the flight is continued. A serious hazard may exist, however, if the extinguishing agent contaminates the cabin air. Substances being used in these systems include carbon dioxide, methyl bromide, and chloro-bromo-methane. Carbon dioxide is the least toxic, but even this material, in a number of episodes, has been discharged into cabin air in such concentrations as to cause violent coughing, nausea, headache, and dizziness. Methyl-bromide systems have a number of advantages —one being that of lighter weight (by comparison with CO_2 systems)—but this material is extremely toxic. Chloro-bromo-methane is much less toxic and is now being substituted for methyl bromide in most fixed systems. It is, however, a narcotic; instead of being intoxicated, victims may be merely put to sleep! A newer extinguishant, di-fluoro-di-bromo-methane, shows great promise and may, in turn, replace chloro-bromo-methane.

New solvents, new degreasing agents, and new fuels and additives to fuels are being introduced. In the military services, at least, we sometimes find materials in use before adequate toxicological research has been carried out. It must be a firm policy of aircraft operating agencies that any new substance carried aloft or used in ground operations must have careful toxicological examination before it is used.

Health Hazards in Air Travel

There are two health problems related to air travel which will be discussed briefly: the spread of communicable disease and the transplantation of harmful insects.

Travel itself—previously by surface means—has for centuries been the principal factor in propagation of communicable diseases and the spread of harmful insects from continent to continent. Influenza, in 1918, was spread around the world in a few weeks—as fast as ships and trains could carry it. Cholera has been transmitted around the world many times through surface travel. We recall the outbreak of cholera in Egypt in 1947, when military personnel en route from India introduced the disease and started an epidemic causing over 10,000 deaths. We remember, too, the outbreak of smallpox in New York City in 1947, when a traveler from Mexico City made the journey to New York during the incubation period of the disease and caused a small epidemic of 15 cases, with two deaths.

In the field of insect dissemination, we saw the dangers of introduction of a new insect species into a country in the 1930's, when the mosquito, *Anopheles gambiae*, was carried from Africa to Brazil by a fast ship. *A. gambiae* is a much more vicious human biter and a much more effective carrier of malaria than any species previously known in Brazil. As the newcomer spread up the coast and inland along the rivers of Brazil, it caused a tremendous increase in deaths from malaria. Under the influence of the new mosquito carrier, malaria took on the appearance of a new disease. The species was finally eliminated from Brazil in 1940—but only after an extremely expensive campaign.

At first glance, it would appear that travel by air might materially increase these hazards. As air-transport speeds enter the 500 m.p.h. bracket, it becomes possible to travel between any two points in the world within the incubation period of practically any communicable disease. A person might, for instance, be

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exposed to a new strain of influenza in Rome on Friday and come down with the disease in Chicago on Sunday morning, exposing new victims not only en route but also at his destination. Or a traveler from Okinawa, infected with Japanese B encephalitis, might easily reach —in less than 1 day—a mosquito-infested rural section of California, where the disease might be propagated. Tse-tse flies might conceivably board an aircraft in central Africa and reach a tropical area in South America in 4 hours!

The threat from these hazards is increased as the network of air lines is expanded and as airports are established within the historic centers of many diseases and within areas infested by several dangerous insects. And as high-density, low-cost air transportation becomes more readily available, economically, new reservoirs of human disease may be tapped.

Actually, however, the record of the airplane in the spread of disease has thus far been remarkably good. There have been only a few instances of the spread of disease through air travel. In 1947, the airplane shared some of the blame for outbreaks of smallpox in Seattle and San Francisco. Servicemen returning from the Far East—some of them by air—brought the disease from Japan and Korea. Eighty-one cases of smallpox and 20 deaths occurred in these outbreaks. Another episode occurred in England in 1951, when an R.A.F. officer flew home from India during what was later found to be the incubation period of smallpox. He exposed a number of people before his own case was recognized, and in the resulting outbreak there were 28 cases and 10 deaths. But instances such as these have fortunately been extremely rare.

In the matter of insect dissemination, as well, aviation appears to have had a relatively good record. There is reason to believe that military air transportation may have contributed significantly to the introduction, during World War II, of 28 new species of insects into Hawaii. A few new species of mosquitoes have apparently been carried to airports in Florida, but fortunately multiplication appears not to have taken place.

What factors have been responsible for aviation's relatively good record? There are several factors, most important of which is the operation of the International Quarantine Program, which was based on long experience with sea travel and was modified to cover air transportation. This program encompasses several groups of activities: (1) control of disease and insects in areas adjacent to international airports by local health agencies; (2) immunization of travelers against several important diseases such as smallpox, yellow fever, and cholera; (3) insect control aboard aircraft in international journeys; and (4) epidemic intelligence, the distribution of knowledge on the world incidence of certain diseases, now accomplished through publications of the World Health Organization. Besides the operation of the International Quarantine Program, another fortunate factor has been the general world-wide improvement in health and sanitation which has been going on concurrently with the rapid expansion of air-transport networks and which will be mentioned again later. Still another favorable factor is that, because of economic selection, the people who travel by air are the best educated, the cleanest, and, in general, the healthiest group of travelers in the world.

Does the International Quarantine Program provide complete control of health hazards in air travel? We should recognize that it does not and that complacency is not justified. Several serious potential threats exist.

(1) The International Sanitary Regulations cover only a few diseases. Dissemination of a number of other important diseases might be accelerated by air travel. Pandemic-type influenza, for instance, might cause a grave threat to world health if it should again occur, since it might be spread around the world in days instead of weeks. In the face of such rapid propagation through air travel, we should not have time to develop and administer proper vaccines.

(2) Even among diseases covered by the International Sanitary Regulations, several hazards exist: (a) Dissemination of smallpox remains a danger because many parts of the world—including most of the U.S.A. —are vulnerable to the introduction of the disease. We now recognize that immunity following vaccination is *not* lifelong; except in a few cities where programs of adult immunization have been carried out, probably less than one-fourth of our population is actually immune. Furthermore, we are becoming aware of some of the pitfalls in administration of vaccine. In 1946, we had 121 cases of smallpox among our troops in Japan and Korea. All of these men had been vaccinated, but it was obvious that the vaccination had not been done properly. (b) Dissemination of yellow fever is a serious potential threat, because, although the disease is at present confined to Africa and South and Central America, the mosquito carriers of the disease are distributed in a broad band around the world. Much of the world is vulnerable to yellow fever because of the presence of significant numbers of *Aedes aegypti;* if infected insects or human patients were introduced into these areas, major outbreaks might occur.

(3) Transplantation of insects is a constant potential threat. Control at airports and aboard aircraft requires diligent, conscientious operators. Automatic insecticide dispensers for use on aircraft have been developed but have not been enthusiastically received, because of technical difficulties. If the vigilance of operators should ever be relaxed, the costly Brazilian experience might be repeated.

Aviation As a Stimulus to Health Improvement

We have considered only some of the health hazards associated with air travel and aircraft operation. Now, by contrast, let us consider some of the improvements in world health for which credit belongs, at least in part, to aviation.

International air travel has accelerated international cooperation in matters of disease control. The International Quarantine Program is not the ultimate answer in control of disease; it is simply a crutch that may be discarded when all parts of the world reach a high level of health and sanitation. But the meetings of the World Health Organization, concerned with the International Sanitary Regulations, have been attended by a degree of international agreement which has been most commendable. One of the meetings produced this concept: "A community is more effectively protected against pestilential disease by its own public health service than by sheltering behind a barrier of quarantine measures." These meetings have coordinated, to a considerable degree, the various countries' solutions of their own health problems.

Furthermore, international air travel has provided a concrete incentive for improvement of health and sanitation. In order to simplify air travel—and in some cases to qualify for it—communities have been required to carry out extensive programs of insect control, sanitation, and health improvement in regions of international airports. Such programs, once begun, are being extended in many instances to the surrounding country.

Aviation is providing still another factor in improvement of health, by extending—through air transportation of patients—the geographic coverage of the great medical centers. In the military services, through air evacuation of patients from the combat zones, we have been able to provide better medical care at less expense than if surface transportation were used. We have avoided costly hospital centers in overseas areas by flying patients back to the United States, where specialized teams and equipment are available. At the School of Aviation Medicine we have developed a rather specialized air evacuation service for the transportation of patients with poliomyelitis. In the past year, we have transported in the neighborhood of a hundred of these patients—many requiring respirator care in flight—from small dispensaries and isolated stations to larger hospitals where proper nursing care is available. A particularly colorful example of the air evacuation program is seen in Alaska, where the Air Force 10th Rescue Group flies "mercy" missions routinely, to the most remote villages in the territory, to pick up sick Eskimos and Indians and bring them to hospitals in larger cities. In civilian life as well, patient transportation is becoming increasingly important. The great medical centers of New York City, the Mayo Clinic, and many other institutions are now drawing their patients from the entire country and even from a large part of the world. Air evacuation is changing many of our concepts on the distribution of medical facilities.

Still another contribution of aviation is the provision of uniquely effective tools for insect control. Conventional-type aircraft and helicopters permit operators to deliver insecticidal sprays to 50 times the area that could be covered by ground crews in the same time and also permit delivery to terrain that would be inaccessible to ground crews. Through the use of aircraft, it has become feasible to control all insect life in critical areas.

Future Requirements

Despite aviation's contributions to health, it still presents several rather unique hazards: rapid dissemination of smallpox, yellow fever, influenza, and perhaps other diseases; the spread of a few species of harmful insects; and certain dangers inherent in aircraft operation and flight. Aviation's record has thus far been surprisingly good. Vigilance in several areas is required if this record is to be maintained:

(1) Aircraft designers and manufacturers are called upon for great contributions in promotion of flying safety and in equipment and procedures to facilitate application of health precautions.

(2) Until world health is brought to uniformly high levels, vigilance is required of aircraft operators in fulfilling requirements of the International Quarantine Program. I might point out that this responsibility is especially heavy on the military services, since military operations sometimes preclude the maintenance of normal quarantine procedures.

(3) Health agencies of the entire world must maintain their alertness and cooperation in controlling not only those diseases covered by International Sanitary Regulations but many other diseases as well. Disease must be controlled throughout the whole world—through sanitation, insect control, and immunization—before we can consider ourselves safe.

(4) Finally, a well-informed vigilant public is required so that health agencies may have proper cooperation and support.

Air Power and New Weapons

(*Continued from page 19*)

tion—nor, I daresay, yours—that most of them are heralded as promising to make one military vehicle obsolete. That vehicle is always the airplane. Older vehicles and ways of war appear in these vague prophecies as somehow more useful than ever.

If we are to be persuaded that the influence of the airplane is really on the decline, other arguments must be used than those filled with phrases like "in the near future," "in the not too distant future," and "just over the horizon."

What is the impact of new weapons on air power? The answer is simple. Air power is the ability to fight in and through the space surrounding the globe. Air power's wartime mission is to destroy the enemy's ability to make war against us.

Air power was created out of vehicles and weapons made available to us by science, and it constantly seeks new ones.

The United States Air Force has never been tied to a single weapon or system of weapons. Its interest excludes only those peculiar to warfare on land or sea—weapons that have been established as the province of other military services. Its interest includes all weapons for fighting in and through the air. Aircraft and air missiles, both inhabited and uninhabited, all contribute to the Air Force mission and are essential parts of an air weapons system.

Piloted aircraft and pilotless aircraft are designed to discharge the same functions under differing conditions and to assist and complement each other under all conditions. Missiles are designed, constructed, and operated in much the same manner as conventional airplanes and usually by the same people. Piloted and pilotless aircraft are guided, directed, and controlled in the same way, by the same devices, and necessarily by the same authority.

Even if our pilots were jealous of missiles, which they are not, the Air Force would continue to sponsor their development in accordance with its principle that a man should never be given a job that a machine can do as well. And we would certainly never waste a man on one that a machine can do better.

I say "continue to sponsor" because the Air Force began developing and flying pilotless aircraft not in World War II but in World War I. Some of you will recall that one of the greatest of all airmen—Gen. Hap Arnold—went to France in World War I as a project officer for the famous "Bug," an early pilotless aircraft.

Let me quote from his autobiography: "Early in the fall of 1917, working with the Sperry Company and with Kettering's Delco firm, we developed—not merely experimented with, but successfully tested—two pilotless planes. One was a full-sized airplane, equipped with complete gyroscope controls."

General Arnold's personal project, the "Bug," was a smaller plane, but it had positive altitude and directional controls activated by a barometer and gyroscope and reached its target by the same kind of preset aiming as the German V-1 of World War II. Tables of Organization were drawn up for air squadrons to launch thousands of "Bugs" a day, but the war ended before General Pershing could give his final approval.

In 1941, General Arnold called in Mr. Kettering and Mr. Knudsen to revive the "Bug" project and bring it up to date, but they abandoned it because of its limited range and low accuracy as compared with piloted bombers. The Air Force used pilotless aircraft to a limited extent later in the war. But only long-range bombers and reconnaissance planes could reach the important targets deep in enemy territory—just as today.

Our concentration on range and accuracy, then as now, was dictated by geography rather than by limitations of technology or by mere personal preference. Germany's huge investment in missiles was also dictated by geography, since England's vital industrial targets were within a missile's easy reach.

In the lean years prior to World War II, General Arnold greatly strengthened the Air Force's link with science and industry. As Hap put it: "Few high-ranking officers seemed aware of the close relationship developing between these specialists and the little Air Corps—a relationship that was to grow to such importance in World War II that civilian scientists would work side by side with staff officers in our overseas operational commands, frequently flying on combat missions to increase their data." He and General Westover were constantly in touch with such members of the National Research Council as Millikan, Bush, Kettering, Compton, Briggs, and Conant.

Once he invited Gen. George Marshall to lunch with a group of these men. "What on earth are you doing with people like that?" asked General Marshall.

"Using them," Hap replied. "Using their brains."

Hap's willingness to use the best brains whenever he could find them helped to shorten World War II. General Spaatz and I continued the practice, and it has now become habitual in the Air Force. We hope it will help to prevent World War III. The Air Force is in no way a competitor of civil manufacturers, civil research agencies, or civilian scientists. Instead, it is their principal sponsor and customer, and it is increasingly dependent upon them.

The Air Force does not indulge in sensational predictions about atomic-powered planes, intercontinental missiles, and electronic robots. Nevertheless, we are working in all these areas and we are making progress. We are putting into missile research and development an effort comparable to what we are devoting to conventional aircraft.

We need your help, more and more of it, for all our projects, and they are many. With the increasing com-

(*Concluded on page 144*)

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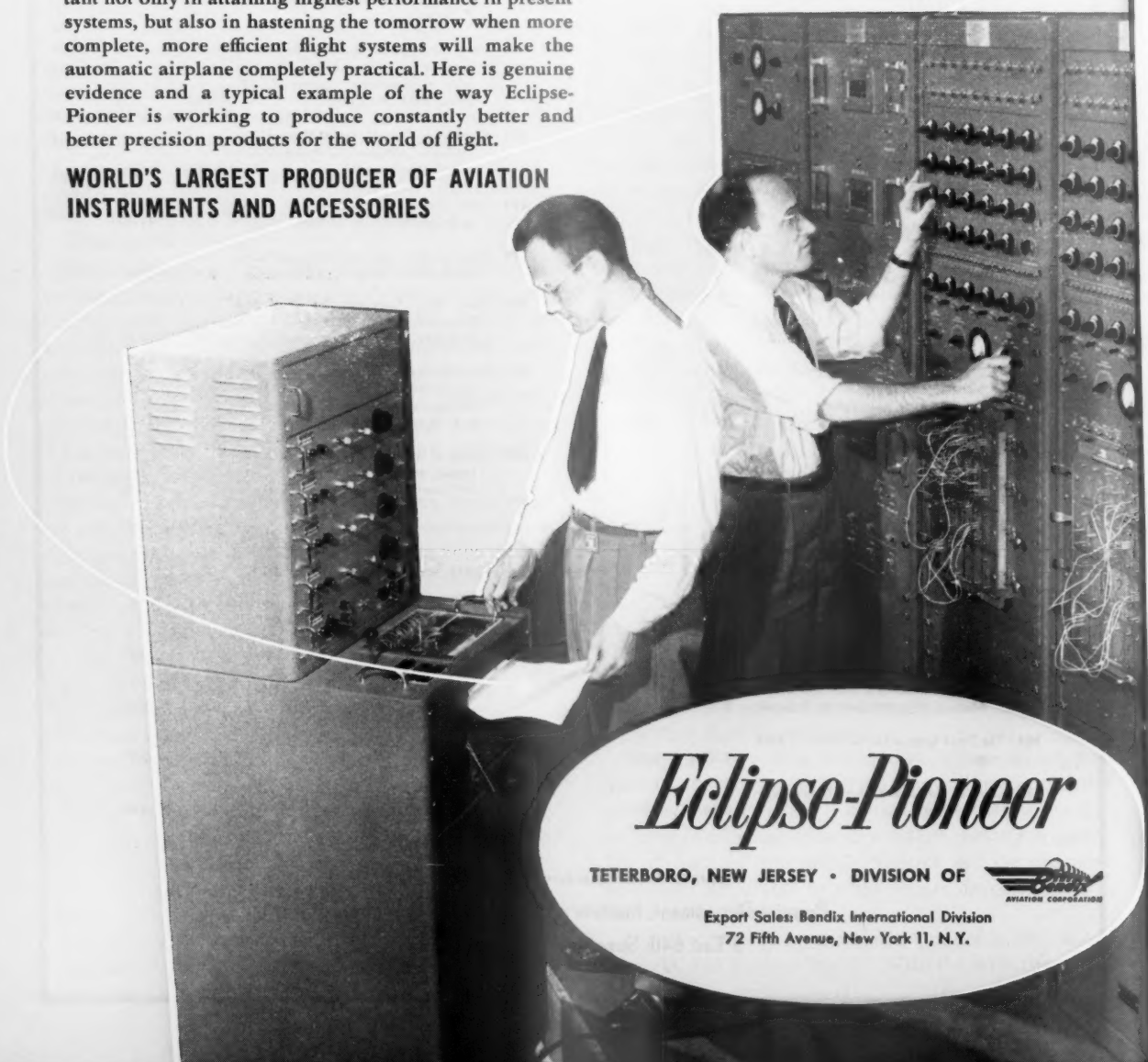

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The Aerodynamic Profile as Acoustic Noise Generator

By

Max Kramer

Coleman Engineering Company

Everybody knows that fast-moving aerodynamic profiles, such as propeller blades, are about the noisiest thing on earth. This noise has been carefully studied in the past. The result was that propeller noise consists of two entirely different components. First, there is the rotational noise that is caused by the variation in distance of the pressure source from the observer. By nature, this noise is mainly emitted in the plane of rotation and contains strong peaks at the fundamental and the harmonics of the number of blades times the revolutions per second. This component of the noise has been theoretically investigated, and there is good agreement with measurements. Second, propeller noise consists of the profile noise, or vortex noise. The profile noise is best heard near the axis of rotation, since there the rotational noise theoretically is zero. Explanations of the origin of this profile noise have often been attempted. However, even the most recent explanation fails to make understandable the outstanding role that the Mach Number plays in profile noise.

The paper discusses a recent explanation of profile noise, reports some new experiments on the matter, and, finally, states the author's opinion on the predominating source of profile noise.

Stability Derivatives for a Slender Missile with Application to a Wing-Body-Vertical Tail Configuration

By

Arthur E. Bryson, Jr.

Hughes Aircraft Company

Theoretical stability derivatives are determined for a slender missile through use of the concept of inertia coefficients of its cross section. The inertia coefficients are determined by the velocity potentials for two-dimensional motion of the cross section in two mutually perpendicular directions and for rotation about an axis perpendicular to the cross section. The inertia coefficients are derived for the cross section of a configuration consisting of a slender body of revolution with low aspect ratio wings and unequal vertical tails.

Oscillating Airfoils at High Mach Number

By

M. J. Lighthill

University of Manchester, England

A simple formula is given for the pressure distribution on an oscillating airfoil in two-dimensional flow at high Mach Number. The formula is expected to be reasonably accurate if the pressure on the surface remains within the range 0.2 to 3.5 times the main-stream pressure. To illustrate the application of the formula, some results for symmetrical airfoils performing pitching oscillations are obtained and compared with results obtained from existing theories in the case of high Mach Number.

An Experimental Study of Natural Vibrations of Cantilevered Triangular Plates

By

P. N. Gustafson, W. F. Stokey, and C. F. Zorowski

Carnegie Institute of Technology

Experimental results are obtained for the lowest six natural frequencies and the associated nodal lines of triangular plates of uniform thickness clamped on one edge. Two series of plates are examined. In one series, a delta-wing plan form of fixed span is maintained, and five plates are examined having aspect ratios ranging from 2 to 20. In the other series, a fixed span and a fixed root chord are maintained, and five plates are examined having mean-chord line sweepback angles ranging from 0 to 45°. Test results are presented by graphs and photographs. These results show that in the delta-wing plan form of fixed span, the frequency of each of the six modes *increases* as the aspect ratio *increases*—that is, as the root chord is made smaller. No such general property is exhibited by the plates in the sweepback series, except for the "bending" modes, where the frequencies decrease with increasing angle of sweepback. A simple method is described for finding the natural frequencies of a plate of any size, thickness, and material, as long as its plan form is similar to one of the plates used in the experiments, or any other plate whose frequencies are known.

Please do not order Preprints of these papers at this time.
See page 83 for Preprints that are immediately available.

Some Effects of Surface Curvature on Laminar Boundary-Layer Flow

By

James S. Murphy

University of Michigan

The laminar flow of a viscous incompressible fluid over a two-dimensional curved surface is investigated for two cases, one in which the curvature is "large" and the other in which it is "moderate." The boundary-layer equations applicable to these cases are obtained as approximations from the exact equations of motion by an order-of-magnitude analysis. These equations are solved for flow over a particular surface with zero surface pressure gradient. In this analysis, the pressure gradient normal to the surface is included, and the outer boundary conditions are modified in accordance with the requirements of flow over a curved surface.

The results indicate that, for equal Reynolds Numbers, the stress on convex surfaces is less than the flat-plate value, while the stress on concave surfaces is greater than for a flat plate. The most important effect of surface curvature, for the cases considered, is the modification of the shape of the velocity profile near the "outer edge" of the boundary layer. The requirement that a smooth

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transition exist between the viscous flow and the potential flow at the outer edge of the layer causes the profiles to have a negative slope near the outer edge for convex surface curvature and a positive slope for concave surface curvature.

Calculation Method for Three-Dimensional Rotationally Symmetric Laminar Boundary Layers with Arbitrary Free-Stream Velocity and Arbitrary Wall-Temperature Variation

By

Robert M. Drake, Jr.

University of California at Berkeley

A calculation method is presented enabling a rapid prediction of the distribution of the local skin-friction and heat-transfer coefficients to be made for rotationally symmetric bodies having arbitrarily specified free-stream velocity distributions and surface-temperature variations for constant-property, incompressible laminar boundary-layer flows. The method utilizes the Mangler transformation as a basis, thus enabling the results calculated by Hartree and Levy for the two-dimensional case to be used directly in the determination of boundary-layer quantities for the three-dimensional case.

Example results using the proposed method are presented in the form of the boundary-layer momentum and displacement thicknesses, the skin-friction coefficients, and the heat-transfer coefficients for a three-dimensional half-body with constant surface temperature. These results, utilizing the Hartree velocity profiles, are compared with similar results obtained by Scholkemeier utilizing the Pohlhausen *P*-4 velocity profiles. The skin-friction coefficient for stagnation-point flow as obtained by the approximate method is compared with the exact solution for this region given by Homann to show excellent agreement.

Conical Potential Solutions in Linearized Supersonic Flow

By

George Morikawa

Office of Naval Research

An important concept in the development of linearized supersonic flow theory is the conical flow theory originated by A. Busemann wherein conical boundary-value problems are considered in which the velocity components are conical. Attention is focused in this paper on strip-type boundary-value problems in which the potential itself is conical. In application, conical potential solutions are useful in the calculation of spanwise and chordwise lift distributions of twisted wings.

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News of Members

(*Continued from page 25*)

the Order of the British Empire for services to civil aviation. Lord Brabazon's name was included in the Prime Minister's New Year Honours List.

▸ **Witold Brzozowski** (M.), Consultant, was recently granted U.S. Patent 2,601,258 for a jet-operated helicopter that expels high-pressure gas from nozzles in the wing tips. Gas, compressed in the fuselage, is piped up through the pylon to the rotor and thence through the blades to the nozzles from which it is expelled into the atmosphere. Mr. Brzozowski has assigned his patent rights to Stefan Czarnecki, of Walden, N.Y.

▸ **George H. Buchner** (M.), Manager, Spare Parts Administration, Northrop Aircraft, Inc., has been elected National Chairman of the Spare Parts Committee of the Aircraft Industries Association. As chairman of this committee, Mr. Buchner is in charge of organizing meetings and programs intended to coordinate spare parts supply activities between the parts and customers.

▸ **Walter Fitch** (A.M.), Consultant, Methods Engineering, Wichita Division, Boeing Airplane Company, was recently elected an Associate of the Royal Aeronautical Society, Great Britain.

▸ **Martin Goland** (A.F.), Associate Director for Engineering, Midwest Research Institute, was recently elected a Regional Councilor of the Office of Ordnance Research. Mr. Goland, as one of eleven regional councilors selected from leading U.S. scientists, will act as liaison between the U.S. Army Ordnance Corps and universities and other institutions throughout the Middle West.

▸ **James Lew** (M.), Contract Administrator, Beech Aircraft Corporation, is heading a special committee recently formed to expedite the production of the Beechcraft T-36A by coordinating the activities of the eight separate departments and divisions concerned with its production and assisting the T-36A subcontractors. Mr. Lew's contract administration duties will be temporarily assumed by his assistant during the period in which this special committee is in operation.

▸ **Dr. Ross A. McFarland** (M.), Associate Professor of Industrial Hygiene, School of Public Health, Harvard University, has had published by McGraw-Hill Book Company, Inc., his latest book, entitled "Human Factors in Air Transportation."

▸ **E. W. Robischon** (M.), Western Region Manager, Institute of the Aeronautical Sciences, was given a 3 to 4 months' leave of absence from his I.A.S. post in order to serve under Dr. Theodore von Kármán, H.F.I.-A.S., as a Consultant to the Advisory Group for Aeronautical Research and Development, North Atlantic Treaty Organization, Paris. Mr. Robischon sailed for France on January 31.

▸ **Vice Admiral Charles E. Rosendahl,** U.S.N. (Ret.) (F.), was on January 26 appointed Executive Director of the National Air Transport Coordinating Committee. The N.A.T.C.C. is the industry-wide civil aviation committee studying air transport problems in the Greater New York Area.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of I.A.S. members. All members are therefore urged to notify the News Editor of changes as soon as they occur.

Dr. William F. Ballhaus (A.F.), Assistant Chief Engineer in charge of Analytical Activities, Northrop Aircraft, Inc. Formerly, Chief of Preliminary Design, Fort Worth Plant, Consolidated Vultee Aircraft Corporation.

C. W. Bogart (T.M.), Aerodynamics Engineer, The Glenn L. Martin Company. Formerly, Aeronautical Engineer, Office of Bureau of Aeronautics Representative, Akron, Ohio.

Joseph M. Chase (A.M.), Manager, Division of Aircraft Maintenance and Equipment, Flight Safety Foundation, Inc. Formerly, Manager, Aviation Underwriting Department, Lumbermens Mutual Casualty Company.

Jerry J. Feldman (T.M.), now Service Engineer, Sales Depar ment, The Aviation Engineering Corporation.

(*Continued on page 90*)

NEW POSITION

William L. Greene (M.) was recently appointed Vice-President—Engineering and General Manager of Engineering and Research Corporation, following the successful completion of the first Flightronic simulators. He joined Erco in 1937 as a Junior Engineer. In later years, as Erco's Chief Engineer, he prepared the company for its entry into the electronic flight simulator field.

PROMOTED BY NORDEN

Boone T. Guyton (M.), who has been in charge of Contract Liaison and Public Relations for Norden Instruments, Inc., was recently named Manager of Government Sales and Service for the company. In this new position, Mr. Guyton retains the responsibilities of his former post. His new duties include responsibility for Norden's Field Service program and its Government sales activity.

JOINS DOMAN

John W. Mazur (M.) recently accepted the position as Chief Design Engineer with Doman Helicopter, Inc. Mr. Mazur, who received his aeromechanical engineering degree from Purdue University in 1939 and his M.S. degree from the University of Maryland not long ago, was formerly Senior Project Engineer, Rotary Wing Branch, Flight Test Division, Naval Air Test Center, Patuxent River, Md.

From left to right: C. W. Lefever, Vice-President, Mid-East Region, A.H.S.; Col. Wm. B. Bunker, Chief, Air Transport Service Division, U.S. Army; Alfred I. Roman, New York; Grahame H. Aldrich, Air Transport Association; Dr. J. A. J. Bennett, Hiller Helicopters, Palo Alto, Calif.; Ralph H. McClarren, Program Chairman, 2nd C.A.C.

2nd Convertible Aircraft Congress

Philadelphia Sections of the I.A.S. and A.H.S. Help Cosponsor December Meeting. Published Proceedings Now Available.

The Pioneers in Convertible Aircraft, together with the local members of the American Helicopter Society and the Institute, held a 1-day meeting in Philadelphia, December 12. Captain Ralph Barnaby, Chairman, and Ralph H. McClarren, Co-Chairman, headed-up the arrangements committee for the Congress. Morning and afternoon technical sessions, a get-together luncheon, and a dinner in the evening gave participants ample opportunity to discuss current developments in the field of convertible aircraft.

Twelve papers were presented during the day in meetings held at the Franklin Institute. Harry Tobey, Chairman of the I.A.S. Philadelphia Section, and C. W. Lefever, Vice-President of the A.H.S. Mid-East area, served, respectively, as chairmen of the morning and afternoon technical sessions. Papers and discussions were presented as follows:

New Comments on Configurations—Louis de Monge de Franeau.

Super Speed Converti-Planes for Military and Commercial Use—Alfred I. Roman.

Composite Aircraft with Rotary- and Fixed-Wing Components—Dr. J. A. J. Bennett.

The Operable Model of the S. S. S. Convertoplane—Gerard P. Herrick.

Jet Propulsion for Convertaplanes—David C. Prince.

Basic Design Philosophy—E. Burke Wilford.

The High-Speed Convertiplane—Frederick M. Gloeckler.

Movies of Free-Flight Model Convertiplane—Lawrence M. Patrick.

Airplane Appraisal of Convertible Aircraft—Grahame H. Aldrich.

The Position of the Convertible Aircraft in Army Aviation—Colonel William B. Bunker, T.C.

Medvedeff Monocopter—Nicholas J. Medvedeff.

When Will the Converted Plane Come?—Antoine Gazda.

The Convertaplane—A Historical Résumé and Definition—E. K. Liberatore.

• **Luncheon and Dinner**—A Luncheon was set up in Franklin Hall, at which time Grover Loening delivered an interesting talk on "Development of Convertiplane."

Dinner, preceded by a cocktail hour and meeting of the "Pioneers," was held at the Hotel Warwick. Approximately 200 guests were entertained by the "toastmastery" of Paul Thomas and an address by the principal speaker, Adm. Charles E. Rosendahl, U.S.N. (Ret.), "Impressions of a Newcomer."

• **Proceedings Available**—A 140-page book, containing all of the papers, discussions, and luncheon and dinner speeches, has been compiled by the Institute as a service to the sponsors. Copies may be obtained from the I.A.S. in New York at $3.00 per copy while the limited supply lasts.

All in One

Bridge Detector
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General Purpose Amplifier

Type 1231-B Amplifier and Null Detector is a battery-operated, resistance-coupled amplifier which may be used as a sensitive bridge detector, a general purpose laboratory amplifier, or as a standing-wave indicator at ultra-high frequencies.

This instrument can be operated either with the usual linear amplifier characteristic or with a semi-logarithmic characteristic which makes it useful as a sensitive visual null detector in bridge measurements. For linear operation, the voltmeter scale has two ranges of two volts and twenty volts, respectively. At the semi-logarithmic position, and at maximum gain, less than 15 microvolts will produce a perceptable meter deflection, while more than 4,500 microvolts are required to drive the meter off scale. A built-in vacuum-tube voltmeter measures output voltage; head telephones can be used for aural indication where preferable.

High sensitivity combined with wide voltage range permits bridge balance with precision and without bothersome gain adjustments.

Features

★ *Gain is greater than 70 db at 10 cycles and greater than 45 db at 100 kc — at midband (1 kc), maximum open-circuit voltage gain is greater than 83 db.*
★ *At "null detector" position, less than 100 microvolts input gives 10% indication on meter at 1 kc.*
★ *At "amplifier" position, less than 25 μv input at 1 kc gives 10% indication on sensitive range of meter.*
★ *Maximum output voltage is 5 volts into 20,000 ohms; 20 volts into 1 megohm.*
★ *Low noise level of 15 microvolts (referred to input) can be further reduced along with hum and harmonics, by connecting external filter to panel jack.*
★ *Input impedance is 1 megohm in parallel with 20 μμf. Output impedance is 50,000 ohms resistive.*
★ *Push buttons provide convenient operation of input attenuator, set the condition of operation, select the meter-scale range and check battery voltages.*
★ *Tubes are mounted on shock-absorbing suspension for minimum microphonic effects.*
★ *Type 1261-A Power Supply Unit can be used to operate the Type 1231-B from 40 to 60 cycle a-c lines; power supply fits into cabinet in place of battery.*

1231-BM Amplifier and Null Detector, Battery operated	$250.00
1231-BMA Amplifier and Null Detector, a-c operated	370.00
1231-P2 400 and 1000 cycle Filter	25.00
1231-P3 60 cycle Filter	20.00
1231-P5 Adjustable Filter (11 frequencies from 50 c. to 100 kc.)	215.00

At ultra-high frequencies, a slotted coaxial transmission line, such as the G-R Type 874-LB, is often used with a traveling crystal detector to measure standing-wave ratios. If the UHF power source is pulsed, or amplitude modulated at an audio-frequency rate, the rectified output may be amplified and detected by the Type 1231-B.

The most sensitive input range enables detection of 5 microvolts in the mid-frequency range. This sensitive range was incorporated into the instrument's vacuum-tube voltmeter specifically for this application.

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Noise Meters ☆ Null Detectors ☆ Precision Capacitors
Pulse Generators ☆ Signal Generators ☆ Vibration Meters ☆ Stroboscopes ☆ Wave Filters
U-H-F Measuring Equipment ☆ V-T Voltmeters ☆ Wave Analyzers ☆ Polariscopes

Myron B. Gordon (A.F.), President, Flight Refueling, Inc. Formerly, Consultant.

Clare W. Harris (M.), Assistant Chief Engineer in charge of Projects and Components, Northrop Aircraft, Inc. Formerly, Chief of Preliminary Design, Northrop.

Orlin M. Jacobson (T.M.), Missile Test Analyst, Guided Missile Division, Consolidated Vultee Aircraft Corporation. Formerly, Corporal, U.S. Army.

Arthur O. Kresse (T.M.), Design Engineer, Thompson Products, Inc. Formerly, Aeronautical Engineer, Ballistics Instrumentation, Ballistic Research Laboratories, Aberdeen Proving Ground, Md.

Edward A. Ledeen (M.), Administrative Engineer, Aeronca Manufacturing Corporation. Formerly, Administrative Engineer, Haines Designed Products Corporation.

Fernand A. Michael (A.M.), Engineer-In-Charge, Engine Build-Up and Propeller Overhaul Departments, Air-India International Ltd., Santa Cruz Airport, Bombay, India. Formerly, Engineer, Propeller Overhaul Department, Air-India Ltd.

John V. Moffitt (M.), now with Southwest Research Institute, Tex.

Warrant Officer Charles E. Savo, U.S.N. (T.M.), U.S.S. "Wright" (CVL-49), c/o Fleet Post Office, New York, N.Y. Formerly, Assistant to Aircraft Engines Officer, Staff, ComAirPac, Naval Air Station, San Diego, Calif.

Rex L. Snell (T.M.), Test Engineer, Fort Worth Division, Consolidated Vultee Aircraft Corporation. Formerly, First Lieutenant, U.S.A.F., Design and Development Officer, 3080th Aviation Depot Squadron, Limestone A.F.B., Me.

Dr. Phrixos J. Theodorides (A.F.), Research Professor, Institute for Fluid Dynamics and Applied Mathematics, University of Maryland. Formerly, Consultant of Aerophysics, U.S. Naval Ordnance Laboratory, Md.

Lysle A. Wood (A.F.), Director of Pilotless Aircraft, Boeing Airplane Company. Formerly Chief Engineer, Boeing.

G. E. Woods-Humphery (A.F.), Chairman of the Board, Flight Refueling, Inc. Formerly, President, Flight Refueling.

Corporate Member News

• **Aeroquip Corporation . . .** According to a recent announcement, George J. Fischer was elected Vice-President, Sales, and Matthew J. Betley was elected Vice-President, Manufacturing. Mr. Fischer was formerly General Sales Manager, and Mr. Betley held the position of Works Manager.

• **Airborne Instruments Laboratory, Inc. . . .** An Applied Electronics Section has been formed in Airborne's Research and Engineering Division.

• **Beech Aircraft Corporation . . .** The latest model of the four-place Beechcraft Bonanza, the D35, was unveiled on January 29, and the first one was delivered 2 days later. The D35 Bonanza cruises at 175 m.p.h. and tops at 190 m.p.h. At sea level, using 20° flaps in a 10 m.p.h. wind, it takes off in 525 ft.; the landing run is 227 ft., using 30° flaps at sea level in a 10 m.p.h. wind.

• **Bendix Aviation Corporation, Bendix Products Division . . .** The recently announced power steering mechanism that replaces the conventional torque link in an aircraft nose strut is said to effect savings in both space and weight by combining steering and normal shock-strut torque-link functions in a single mechanism. The steering force, it is said, is accomplished by power cylinders that replace the upper torque link of the usual shock strut, while the lower link remains essentially the same. Control of the complete unit is provided by a control valve operated by the pilot. Thus,when the plane is taking off, landing, or taxiing, the pilot sets the hydraulic forces into motion to steer the ship to the right or left or to hold it steady in forward motion by simply moving a small lever located on a control box at his side. This steering device also provides for shimmy dampening.

• **Boeing Airplane Company . . .** Lysle A. Wood, A.F.I.A.S., Chief Engineer of Boeing since 1948, was recently appointed to the newly created post of Director of Pilotless Aircraft. A substantial portion of the aircraft engineering responsibilities have been shifted to George C. Martin, Chief Project Engineer—Aircraft, and to George S. Schairer, F.I.A.S., Chief of Technical Staff. In addition to the duties attending their respective positions, Mr. Martin has added the service unit and engineering administration functions to his responsibilities, while Mr. Schairer has taken over the overall direction of preliminary design and flight test. R. H. Jewett will continue as Chief Project Engineer—Pilotless Aircraft.

• **Consolidated Vultee Aircraft Corporation . . .** The new air-evacuation transport ordered from Convair by the U.S.A.F. has been named the C-131A "Samaritan." The Samaritan is based on the design of the Convair-Liner 240 Transport. It can accommodate 16 litters and 20 rearward-facing seats or can have an alternate arrangement of 20 additional seats in place of the litters. The first of these ships is scheduled for delivery in the spring of 1954. . . . The 80-ton turboprop transport seaplane, the R3Y, has been officially named "Tradewind." This seaplane has been pressurized for high-altitude cargo-transport operations. Its maximum speed is over 350 m.p.h., and it takes off within 30 sec. in a calm. The Tradewind is powered with four Allison T40 turboprop engines, each of which develops 5,500 hp. and is equipped with contrarotating Aeroproducts propellers.

• **Douglas Aircraft Company, Inc. . . .** The DC-7, which, according to company claims, will be the world's fastest piston-powered transport, was scheduled to make its first flight during the latter part of March. The DC-7 will have a top speed of more than 400 m.p.h. and a cruising speed of about 360 m.p.h. Depending upon the seating arrangement, the DC-7 will accommodate between 60 and 95 passengers.

• **Edo Corporation . . .** Cy Fenn, who is now in his eighteenth year at Edo, has been named Chief Engineer—Mechanical of the corporation. As such, Mr. Fenn is in charge of all design and engineering work involving nonelectrical equipment produced by Edo. He was formerly Assistant Chief Engineer—Mechanical.

• **Esso Standard Oil Company and The M. W. Kellogg Company . . .** A contract has been awarded to Kellogg by Esso for a 60,000 barrel per day crude distillation unit at Esso's Bayway (N.J.) refinery. The unit will be a three-stage plant similar in design to two now under construction by Kellogg for Esso at its Baton Rouge refinery. Construction is scheduled to start early this summer.

• **Flight Refueling, Inc. . . .** Myron B. Gordon, A.F.I.A.S., who was formerly a Vice-President of Fairchild Engine and Airplane Corporation, was named President of the corporation. G. E. Woods-Humphery, A.F.I.A.S., became Chairman of the Board. Remaining as a Director is Sir Alan J. Cobham, Chairman of the Board and Managing Director of Flight Refuelling, of England, from which the controlling interest in the American firm, Flight Refueling, was recently purchased by Laurance S. Rockefeller, A.M.I.A.S., Reaction Motors, Inc., and associates.

• **Flight Safety Foundation . . .** Lieutenant General Elwood Richard Quesada has been named to Flight Safety's Board of Governors. General Quesada was at one time Commanding General of the Tactical Air Command; he is now Vice-President and a Director of Olin Industries.

• **General Electric Company . . .** The Air Force has approved the construction of a new soundproofed addition to G-E's plant near Johnson City, N.Y. This new building, to be finished some time this year, will be used for complete controlled testing of aircraft armament systems being built by G-E for U.S.A.F. bombers. The building will cost in the neighborhood of $600,000, while the entire project, including special equipment for test cells, will total about $980,000. . . . A new Aviation Division office has been opened in Midwest City, Okla., and will maintain close liaison with the U.S.A.F. maintenance and supply groups in the Oklahoma City area. It is located at 207 Post Office Building in Midwest City.

• **G. M. Giannini & Company, Inc. . . .** The recently introduced $1^1/_8$-in.-diameter multiple-section potentiometer is available in assemblies of one to six sections with a six-section unit requiring an operating torque of 0.6 oz.-in. Operating temperature range is from −54 to +71°C. The unit will function during 50*g* acceleration applied along any axis, the company states.

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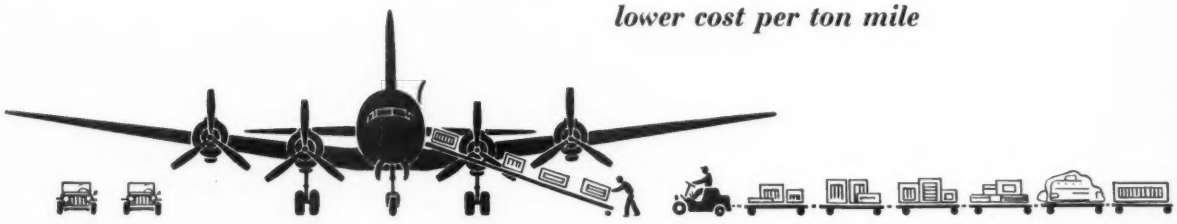


___the Douglas Liftmaster

Flying for the Air Force as C-118A and for the Navy as R6D, the Douglas Liftmaster delivers 14-ton payloads 2850 miles non-stop—at the lowest cost.

Outside, Liftmaster shows the same aerodynamic lines as its commercial counterpart, the DC-6A. Inside, there's room for 28,700 pounds of mixed freight. Large front and rear doors service cargo compartments. A self-powered loading elevator lifts 4,000 pounds from truck bed height to cabin floor level . . . fits either door. Through this combination of speed and utility, Liftmaster achieves the ultimate in long-range, low-cost transportation of military matériel.

Performance of the Liftmaster is further proof of Douglas leadership in aviation. Planes, produced in quantity *to fly faster and farther with a bigger payload*, are a basic rule of Douglas design.

Depend on *DOUGLAS* **First in Aviation**

• **Harvey Machine Company, Inc.** . . . Plans for the construction of the first rolling mill on the Pacific Coast for the production of aluminum sheets, strips, and circular shapes have been announced by the company. Construction of this new $20,000,000 plant will begin as soon as a site is selected, it was said. The entire project will be built by private financing. This new rolling mill, when completed, is expected to have a capacity sufficient to supply a substantial portion of the aluminum sheet and strip needs of the Pacific area manufacturers of aluminum products. Another recent announcement told of plans to build an aluminum reduction plant in Oregon.

• **Jack & Heintz, Inc.** . . . A recently published technical bulletin, designated *J & H File No. 1500*, covers aircraft reciprocating and turbojet engine starters and aircraft-type tank starters. The bulletin includes complete descriptive data, performance curves, cutaway drawings, and photographs of the company's complete line of starters.

• **The M. W. Kellogg Company** . . . In order to service the Kel-F requirements on the West Coast, new warehousing facilities have been established in Vernon, Calif. This plastic is said to have found important applications in the aircraft, chemical, and electronic industries.

• **McDonnell Aircraft Corporation** . . . Sidney W. Souers has been elected to the Board of Directors. Mr. Souers was the first Director of the Central Intelligence Agency and was Executive Secretary of the National Security Council from 1947 to 1950.

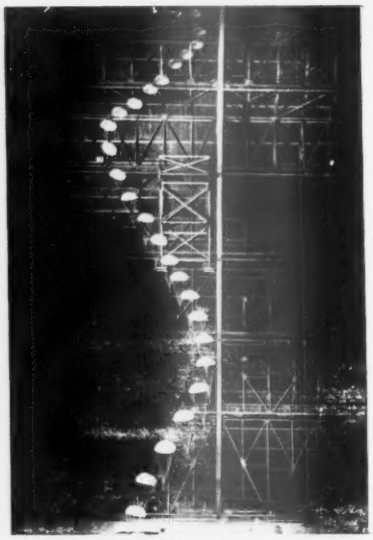
• **Northrop Aircraft, Inc.** . . . Construction of an addition to the flight test and modification facilities at Ontario (Calif.) International Airport was begun on January 21. When completed, the buildings that comprise this new unit will have a total area in excess of 60,000 sq.ft. on a 33-acre site leased from the city of Ontario.

• **Republic Aviation Corporation** . . . Edward S. Moore, Jr., Executive Vice-President of the National Biscuit Company, has been elected a Director of Republic.

• **Rohr Aircraft Corporation** . . . Pacific Airmotive Corporation has now been licensed by Rohr to handle the exclusive manufacture and sales of the Rohr Tilting Arcs. P.A.C.'s Burbank Aircraft Division will manufacture the arcs; the Aviation Products Division will take care of the sales on a national and international basis. The Rohr Tilting Arc was designed primarily to expedite the handling of aircraft engines, engine assemblies, and complete engine nacelles. Rohr Aircraft has been manufacturing tilting arcs at its Chula Vista, Calif., plant for a number of years.

• **Solar Aircraft Company** . . . A recently published booklet on *Shell Mold Castings of Stainless Alloys* can be obtained through Solar's Stainless Steel Foundry in San Diego.

• **Sperry Gyroscope Company, Division of The Sperry Corporation** . . . Carlyle H. Jones, who for the past 2 years has served as Manager of Public Information, has been appointed Director of Advertising and Public Information of the Sperry Gyroscope Company.



PARACHUTE TESTING AT GOODYEAR

Through the use of a stroboscope, the drag and stability characteristics of a falling parachute are shown during a 175-ft. drop test from the ceiling of Goodyear Tire & Rubber Company's current-free airship dock at Akron, Ohio. This is part of a research program that deals with the free-fall tendencies of parachutes. This program is being accomplished by a staff of engineers from Goodyear Aircraft Corporation's Research and Development Department in accordance with the terms of a contract with the Equipment Laboratory of Wright Air Development Center, Wright Patterson A.F.B., Ohio.

• **Standard Oil Company of California** . . . The first preignition-proof compounded oil to be developed successfully for light-aircraft engines has been placed on the market. This lubricant, known as the New RPM Aviation Oil, was designed primarily for executive and personal aircraft engines by Standard's research subsidiary, California Research Corporation. Flight testing of the oil has been carried on for the past 2½ years in 36 airplanes powered by most of the popular light-aircraft engines. It will be available in all grades—55, 65, 80, 100, and 120.

• **Vard, Inc.** . . . A booklet entitled *Vard Brochure* has been published to acquaint the aircraft and allied industries with the products and facilities of Vard. It is available to the industry upon request.

• **Westinghouse Electric Corporation** . . . Four Westinghouse-built motors—two rated at 83,000 hp. each and the other two rated at 25,000 hp. each—are slated for installation in tandem fashion before long in transonic and supersonic wind tunnels now being built at the Arnold Engineering Development Center, Tenn. Five compressors for the wind tunnels are also being constructed by Westinghouse. One of these compressors is destined for the transonic unit, while the remaining four will be coupled as one for the supersonic unit. The compressor blades will measure 2 ft. across the face and 6 ft. in length; they will rotate on a spindle 18 ft. in diameter. . . . E. V. Huggins was recently elected to the newly created post of Vice-President of Corporate Affairs. He was also elected President of Westinghouse Radio Station, Inc. At the same Board of Directors meeting, Joseph E. Baudino was elected Executive Vice-President in charge of all operations.

I.A.S. Sections

Atlanta Section

Edith Hall Lively, *Secretary*

A dinner meeting was held on January 8 at Georgia Institute of Technology. Chairman George Baughman presided and introduced the guest speaker, William Wallace, of General Electric Company, who delivered an interesting talk on the "History of Jet Engines."

Mr. Wallace began his talk with a reference to the "aeolipile," a reaction engine built by Hero of Alexandria in the second century B.C. and reputed to be the first apparatus converting steam pressure into mechanical power. He then touched upon Sir Isaac Newton and the jet-propelled steam carriage that demonstrated his third law of motion and upon John Barber who in 1791 was issued the first patent for a gas turbine. He continued by citing the efforts of Deval and Curtiss, of Armengaud and Lemale, of Dr. Moss, and of other early workers in the gas-turbine field.

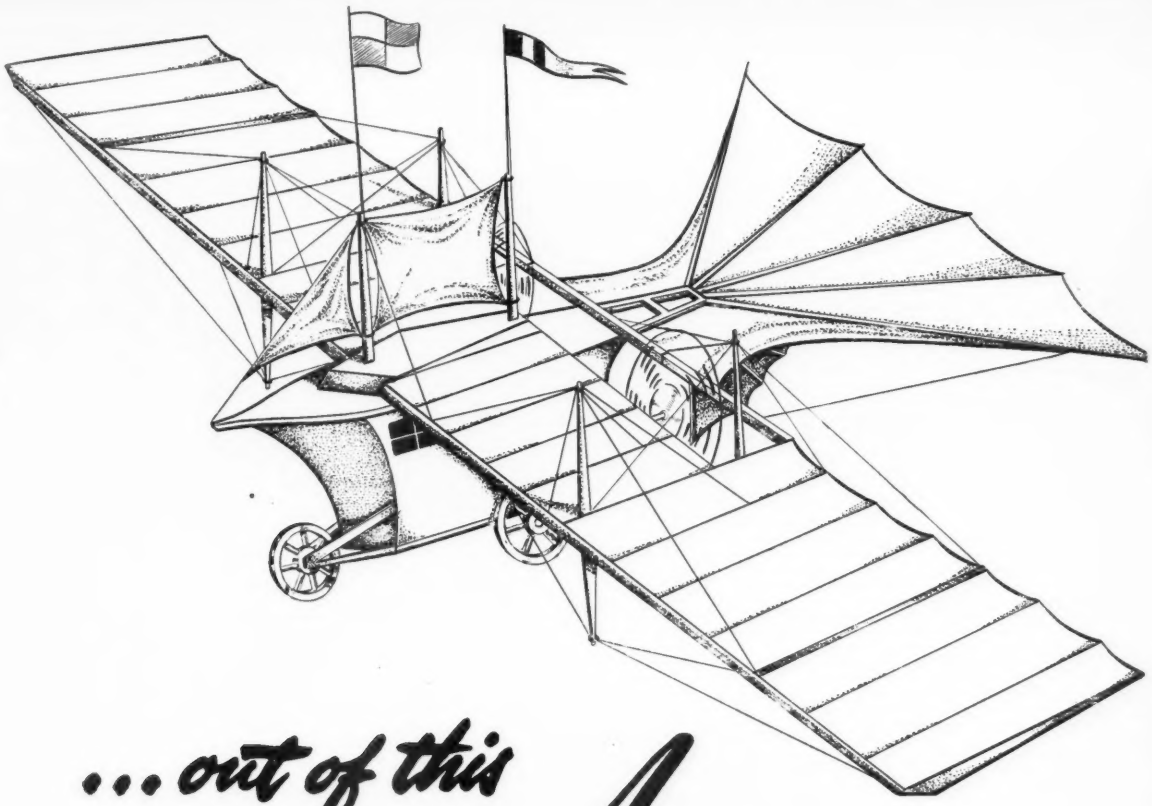
Bringing his history of the jet up to the present day, Mr. Wallace covered the work of Sir Frank Whittle; the first successful flight on May 15, 1941, of a jet-powered aircraft (the Gloster E28/29 powered by the W1 engine); the first successful flight in the U.S.A. of a jet-powered aircraft in October of 1941 (the Bell XP-59A powered by two General Electric 1-A turbojets); etc. He concluded his talk by referring to General Electric's role in jet-engine development, their latest production engines, and other current projects.

A 15-min. color film, *Jet Propulsion*, brought the meeting to a close.

Baltimore Section

J. Francis Maloney, *Secretary*

The thirty-ninth meeting of the Baltimore Section was held in Maryland Hall



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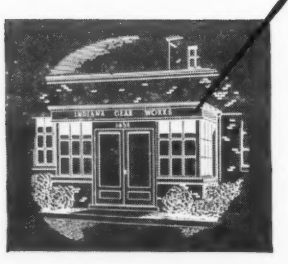

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of The Johns Hopkins University on December 11 at 8:30 p.m. There were over 100 members and guests present.

The three speakers were all from Human Factors Directorate, Air Research and Development Command.

The first speaker, Col. Don Flickinger, Director of Human Factors, outlined the general principles and philosophy associated with the problems of man versus robot. The bio-engineer establishes the physiological parameters that govern the human being. Man is always going to want to fly, and his reliability and adaptability are an essential part of a weapon system

Dr. Al Hetherington, Chief of Environmental Physiology Branch of the Division of Aero-Medical Sciences, spoke of the environmental physiology effects caused by factors in a physical environment and the means of protection from these stresses. The object of protection is primarily to have a normal unimpaired man preserved to do the job he has to do. The human being is a special machine affected by the following physiological factors: air pressure and changes, sound and vibration, acceleration and deceleration, temperature extremes, radiation hazards, and toxic gases and liquids.

The air-pressure requirement is one of supplying sufficient oxygen for the internal combustion (metabolism) of the body. The solution is to supercharge the body or carry air in the vehicle. Carrying enough oxygen soon proved to be impractical, and engineers found that pressurized compartments could be built.

At 40,000 ft. few persons are immune to the bends, and even pure oxygen is not sufficient so that pressurized cabins are the only solution. At 50,000 ft. human life is maintained for only about 15 sec. without mechanical aids. The mechanical effect of having gases expand inside the body is not dangerous unless it occurs in 0.02 sec. In a large bomber, explosive decompression would not occur so rapidly, but, in a fighter, with its smaller volume, the problem of decompression rate is serious. The partial pressure suit is an answer.

The sound and vibration is outflown by the source, but ground personnel must be protected by source sound suppression. Temporary or permanent hearing impairment can be caused, as well as more widespread and little understood effects on the body as a whole, such as buffeting of the body tissue.

With regard to acceleration and deceleration, most men can tolerate 4g sitting and black out above 4g. The rate of application and time of application of the g's are factors. For a while and in the proper place, 17g's can be withstood. The G-suit adds about 2g to the sitting tolerance.

For extremely cold temperature, enough clothing can be worn, but, for high temperature, not much can be done as yet. For a few minutes (5 to 10), 260°F. can be withstood. Temperatures in some experimental airplanes have reached 160°–180°. High temperature has a sunstroke effect. Air-conditioning the man with a suit of flexible material is a solution.

Radiation energy from the sun presents no great problems below 50,000 ft., but, above this altitude, not much is known about what will be encountered.

Toxic gases and liquids introduced into air-conditioning ducts by breakage of hydraulic or fuel lines can generally be lessened by maintenance.

The third speaker, Lt. Col. George Long, Chief of Human Engineering Division, spoke on the failure of the designer to take into account the capabilities of the human being when equipment is designed. Some functions are best performed by man and some by machines. Man has maximum and minimum rates of absorption of information. Since man is a poor monitor, thought has been given to machines for monitoring man. One of the big problems is the overloading of man's eyes. In this connection, arrangement of instruments is extremely important.

In the open discussion that followed, it was pointed out that the concept of machines being an extension of man had been minimized. The discussion also lead to reiteration of the team concept whereby engineers and scientists of all branches must work together to make the most progress.

▶ The fortieth meeting of the Baltimore Section was held in Maryland Hall of The Johns Hopkins University on January 21 at 8:30 p.m. Approximately 50 members and guests were present.

In his discussion of "Problems in Hypersonic Wind Tunnel Research," Dr. Peter P. Wegener, Deputy Chief of the Aero-physics Division of the Naval Ordnance Laboratory, pointed out that there are essentially two problems, high pressure and high temperature.

By means of illustrative slides, the speaker clearly showed the problems involved and explained the advantages of the hypersonic tunnel over free-flight research.

Interest in the speaker's subject was evidenced by the numerous and thoughtful questions asked by the audience.

Chicago Section

Charles L. Bonnette, *Secretary*

On January 6, the Chicago Section members, through the courteous efforts of F. Corneliussen, Office Personnel Manager, were the guests of the Reynolds Metals Company, McCook, Ill.

The members gathered informally in the lobby of the main office building, and at 8:00 p.m. the group was divided and conducted upon a tour of the plant facilities. During this tour, the group witnessed the actual manufacture of aluminum sheets, including the alloying and casting of the pigs, molding and cladding of the ingots, and rolling the ingots through various stages into sheets. The tour proved to be interesting and highly informative to the attending members.

Refreshments were served to all participants at the conclusion of the tour. The evening's activities were concluded at approximately 10:30 p.m.

Hampton Roads Section

H. Herbert Jackson
Recording Secretary

Lieutenant Colonel O. D. Simpson, U.S.A.F. Intelligence, addressed approximately 50 members and guests of the Hampton Roads Section on December 18. Colonel Simpson was stationed in Japan at the outbreak of the hostilities in Korea. The subject of his talk was "The Status of U.S.A.F. Intelligence at the Outbreak of Hostilities in Korea." The talk was classified confidential, and all those attending had to have security clearance.

Colonel Simpson told of the status of our air power in Japan on June 25, 1950. With the aid of a wall map of Japan and Korea, he pointed out where the various fighter-bomber, light-bomber, and other units were located at that time. With the aid of the map, he also brought out the details of the operations and deployments in the early stages of the war.

In reviewing the details of the early stages of the war, Colonel Simpson gave his opinions on changes that would have been necessary to have averted conditions that existed in the Far East prior to the Korean War. He concluded his talk by giving his opinions of the necessary action on the part of the various aeronautical and military groups which would be needed to avoid a repeat of the conditions that existed June 25, 1950.

An interesting discussion period was held after the talk.

Los Angeles Section

Harold S. Fischer, *Secretary*

The Los Angeles Section of the I.A.S. has presented several interesting meetings on a wide variety of subjects in the last few months. On December 4, 1952, Ivan E. Speer, Project Engineer of AiResearch Manufacturing Company of Arizona, addressed a Specialist Meeting on "Design Considerations and Development of a Broad Range, High

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Efficiency Centrifugal Compressor for a Small Gas Turbine Compressor." Mr. Speer discussed the theory and development of a gas turbine suitable for supplying compressed air from its own compressor for the driving of aircraft accessories.

▶ Another Specialist Meeting on December 11, 1952, featured Lee Cahn, Chief Computer Engineer of Beckman Instruments, Inc., who discussed the "Evaluation and Use of Analog Computers," with respect to accuracy figures of merit, cost, and operation. Demonstrations were given of the use of actual computer equipment in solving problems in jet-engine fuel flow and airplane damping in yaw.

▶ The feature January event was the Wright Brothers Lecture by William Littlewood, Vice-President—Engineering, American Airlines, Inc., presented in Los Angeles, by Otto E. Kirchner, Director of Operational Engineering of American Airlines. An audience of about 350 people enjoyed the lecture and the prepared comments of Ernest G. Stout, Assistant Chief Engineer of Consolidated Vultee Aircraft Corporation, San Diego; Warren T. Dickinson, Executive Engineer of Douglas Aircraft Company, Inc., Santa Monica; and Clarence L. Johnson, Chief Engineer, Lockheed Aircraft Corporation, Burbank.

▶ On February 2, 3, and 4, 1953, the I.A.S. was co-sponsor with the American Rocket Society of a presentation by the Department of Engineering of the University of California at Los Angeles, of Professor Luigi Crocco, Goddard Professor of Jet Propulsion at Princeton University, who delivered three lectures on the "Theory of Viscous Supersonic Flows Involving Separation." The lectures were on the topics of (1) "Fundamental Equations and Discussion," (2) "Application to Base Pressure Problems," and (3) "Application to Boundary Layer-Shock Interaction."

▶ "The Use of Adhesives in Primary Aircraft Structure" was the topic of a record attendance Specialist Meeting on January 22, 1953. Approximately 180 engineers concerned with this specialty heard Dr. N. A. De Bruyne, Managing Director, Aero Research Ltd., of Cambridge, England, discuss British developments of adhesives and bonded joints for use in such aircraft as the de Havilland "Comet."

San Diego Section

Earl R. Hinz
Corresponding Secretary

Two dinner meetings were held by the San Diego Section during the month of January. The first of these took place on the evening of January 9 in the Marine Room of the San Diego Hotel

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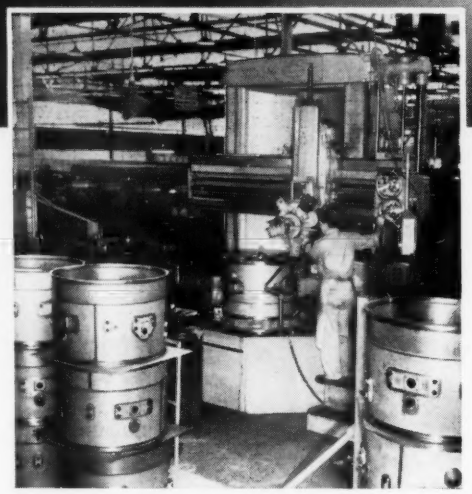

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San Diego Hears Dr. Von Braun: *A new attendance record was established at a joint meeting of the I.A.S. and S.A.E. San Diego Sections on January 21, when 450 persons gathered to hear Dr. Wernher Von Braun (right) speak on "Space Superiority as a Means for Achieving World Peace." Dr. Von Braun was introduced by Dr. Hans Friedrich (M.I.A.S.) (left).*

overlooking the beautiful San Diego Harbor. The guest speaker was Otto E. Kirchner, Director of Operational Engineering for American Airlines, Inc.

The speaker was introduced by Dwight Bennett, 1952 I.A.S. Area Councilor. Mr. Kirchner presented William Littlewood's Sixteenth Wright Brothers Lecture on "Technical Trends in Air Transport." Prepared comments on the paper by Frank Fink, Chief Engineer, Consolidated Vultee Aircraft Corporation, were read and were discussed by Mr. Kirchner. An additional open discussion period followed which had to be limited because of the late hour.

▶ The second January meeting took place on January 21 at the House of Hospitality in scenic Balboa Park in the heart of San Diego. This meeting was the annual joint meeting with the San Diego Section of the Society of Automotive Engineers. The widely known rocket expert and leading proponent of the manned satellite of earth, Dr. Wernher Von Braun, presented his ideas on "Space Superiority as a Means for Achieving World Peace." Dr. Von Braun used many interesting slides to illustrate his engrossing talk on multistage rockets, space orbits, space platforms, and other subjects previously considered the private realm of science-fiction writers.

F. E. McCreery, Jr., Chairman of the S.A.E. San Diego Section, was the Meeting Chairman. Dr. Hans Friedrich, I.A.S. member and former coworker of Dr. Von Braun, gave the highlights of the guest speaker's professional background and also introduced him.

The interest of the San Diego area technical people in this new frontier of science, and adventure, was well proved by an attendance of 450 persons for dinner and the meeting. This constituted a new attendance record for both the I.A.S. and S.A.E. San Diego Sections, individually or jointly.

Texas Section

Howard F. Marx, *Secretary*

"Escape and Bail-Out at High Speeds and High Altitudes" was the subject of the January 23 dinner meeting at the Midway Inn in Arlington, Tex. The principal speaker was Dr. Fritz Haber of the U.S.A.F. Department of Space Medicine, San Antonio, Tex.

Dr. Haber contrasted the problems associated with escape at very high altitudes with those at present. Keeping the parachutist warm at 20,000 ft. is a problem today, but keeping him cool during the initial portion of a descent from 300,000 ft. will be a problem tomorrow. Dr. Haber stated that very high temperatures can be sustained by the human body for short periods of time. Temperatures ranging between 200° and 250°C. have been sustained for approximately $1^1/_2$ min., without permanent injury. Dr. Haber briefly discussed the escape capsule as a solution to the overall escape problem.

After the formal presentation of the talk, a panel of experts consisting of Dr. Haber; Robert Moller, Senior Flight Test Group Engineer, Consolidated Vultee Aircraft Corporation; and Harry Bracket, Test Pilot, Chance Vought Aircraft Division of United Aircraft Corporation; was convened by F. A. Curtis, Convair Senior Aerophysics Engineer. The panelists discussed high-altitude opening shock, use of autorotation escape devices, and possible dangers from cosmic radiation during descent.

A "get-acquainted" social hour preceded the buffet dinner and created an appropriate atmosphere for high-altitude bail-out.

Chairman William Clegern held a brief business meeting prior to the formal program, at which time plans for the First Annual Student Paper Competition were reviewed. The competition will be held during the period from May 6 through May 9.

Attention Members!

All members of the Institute are invited to submit material concerning their activities for publication in the "News of Members" columns of the *Aeronautical Engineering Review*.

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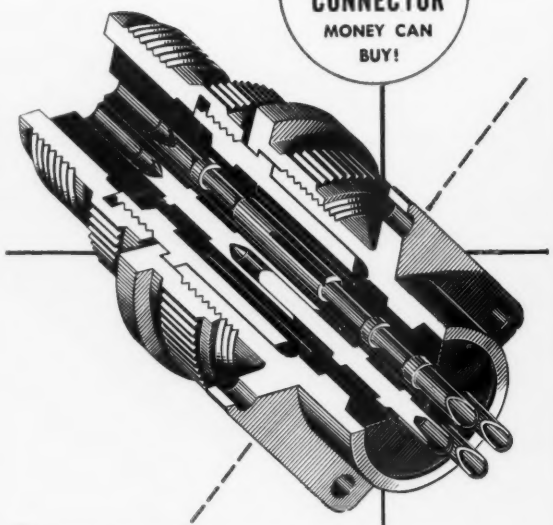

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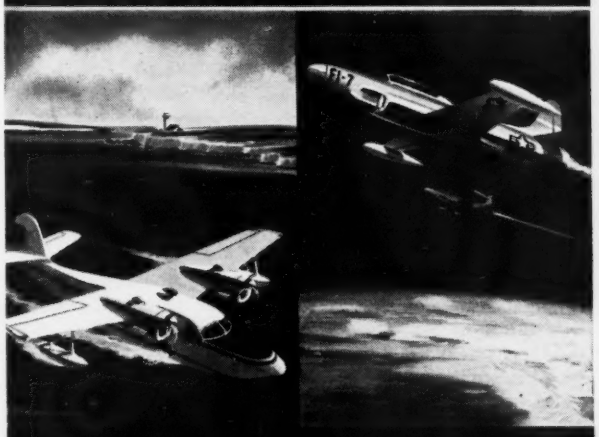
From Water Level To Stratosphere...



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Student Branches

Academy of Aeronautics

Frederick Berger, *Secretary*

The meetings of January 8, January 22, and February 5 were well attended inasmuch as they concerned the nominations and elections of new officers. As a result, the following persons were elected to office: Chairman, G. Ludwig; Vice-Chairman, C. Kozlowski; Corresponding Secretary, K. O'Connor; Recording Secretary, D. Tepper; and Treasurer, K. Dibble.

A total of five films was shown at the three meetings: *The Navy Phantom* (courtesy of McDonnell Aircraft Corporation); two helicopter films from Sikorsky Aircraft Division of United Aircraft Corporation; *The Story of the Flying Wing* (courtesy of Northrop Aircraft, Inc.); and *Special Showing of Latest Aircraft* (courtesy of North American Aviation, Inc.).

Chairman Sherman Martin presided.

The Aeronautical University, Inc.

Robert Johnson, *Secretary*

The following students were elected to office at the January 9 meeting: Chairman, Ralph Flentge; Vice-Chairman, Verne Sprunger; Secretary, Robert Mueller; and Treasurer, Miss Gene Pick. Alfred F. Stott, Dean of Engineering, is the Honorary Chairman and Faculty Adviser.

The Shell Oil Company film on *How an Airplane Flies* was shown to the 19 attending students. This film contains six parts on lift, drag, thrust, and weight; it shows how each is produced and how each of these forces affects an aircraft in flight. The subject of stability is also covered by this film.

Chairman Lyman Welliver presided.

University of Alabama

Curtis G. Harvey, *Secretary*

The January 13 meeting was called to order by Chairman Richard J. Berman. The election of officers for the 1952–1953 spring semester was as follows: Chairman, Shannon Williford; Vice-Chairman, Luke Boykin; Secretary, Curtis G. Harvey; and Treasurer, William Carr.

Catholic University of America

William G. Elsen, *Secretary*

At the January 14 meeting of the Catholic University Student Branch, Dr. Albert May, a Physicist at the Naval Ordnance Laboratory in Washington, D.C., gave a timely talk on the use of the firing range in aerodynamics. He described and showed by means of slides the two firing ranges at N.O.L. and fully explained the workings of these ranges.

As a fired projectile travels along the range, it trips photoelectric cells that are placed at measured intervals along the projectile's course, thereby causing a spark to produce a shadow picture of the projectile and its shock waves to be recorded on film. From sequences of pictures taken in this manner, much is learned of the behavior of differently shaped bodies at supersonic speeds. Dr. May explained how the photographic data were interpreted to give usable conclusions, as well as comparisons of variously shaped projectiles. He passed among his audience sample projectiles and answered the many questions put to him by the students.

The meeting was attended by 18 members; Chairman Earl Erickson presided.

▶ J. B. Hippler, Acting Head of the new Transonic Branch at the David Taylor Model Basin, was the featured speaker at the February 4 meeting. He told the group of the development of the 7- by 10-ft. transonic tunnel now under construction at the basin, much of which

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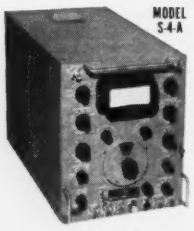

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was formerly a German subsonic tunnel brought to this country from Germany after the war. The original tunnel has been completely redesigned for transonic work and is expected to give a maximum Mach No. of 1.2.

A large amount of new equipment must be designed before this tunnel can be placed in operation, and much of the construction is still to be completed. It will be the middle of 1954 before this tunnel can work and contribute information to the relatively unexplored and little-known field of transonics, which has become so important in modern aeronautics.

University of Cincinnati

Roy J. Matz
Publicity Committee Chairman

The film, *Harnessed Lightning*, was presented at the January 19 meeting, which was attended by 15 students and led by Chairman Roger A. Wingert. This film deals with the principles of jet propulsion and the development of the aircraft gas turbine by the Allison Division of General Motors Corporation.

▶ On February 2, Dr. Raymond Walters, President of the University of Cincinnati, presented the annual Ferdinand L. Weston Memorial Achievement Awards, which are granted to the three aeronautical engineering seniors having the highest scholastic records for their undergraduate work. This year the awards were granted to the following members: the first prize went to Richard L. Wohlen; the second prize to Roger A. Wingert; and the third prize to Roy J. Matz.

At the conclusion of the presentations, a McDonnell Aircraft Corporation film, *Blueprint for Your Future*, was presented. It outlines the opportunities and advantages extended to members of the engineering profession by this particular corporation.

Chairman Wingert presided. Twenty-four students were in attendance.

Georgia Institute of Technology

Robert T. Stancil, *Secretary*

The following officers were elected at the December 8 meeting: Chairman, Sidney Alan Powers; Vice-Chairman, Jack D. McCallister; Secretary, Robert T. Stancil; and Treasurer, Lee T. Allen.

University of Illinois

Ron P. Arnold
Outgoing Secretary

The principal business for the January 14 meeting, the last of the fall semester, was the election of new officers for the spring semester. They are as follows: Chairman, Rex Whitehurst; Vice-Chairman, Frank Vileta; Secretary, Dwight Moberg; and Treasurer, Richard Cole.

The Branch's award to the senior with the highest grade-point average was given to Richard Camp.

Two films that were shown during the meeting were well received. These were on the helicopter, "Little Henry," and the fighter aircraft, "Voodoo."

Outgoing Chairman Gordon D. Booz presided; 35 persons were present.

University of Notre Dame

Thomas Lindsay, *Secretary*

The Notre Dame Student Branch of the Institute of the Aeronautical Sciences held its annual banquet on December 11 in the new Morris Inn on the campus. Chairman Bob Sebold "emceed."

F. N. M. Brown, Head of the Department of Aeronautical Engineering, told the group that the department has made excellent progress in all respects, and enrollment in the Department is increasing substantially. The new supersonic wind tunnel, nearly finished, is the largest privately owned and financed supersonic tunnel in the country.

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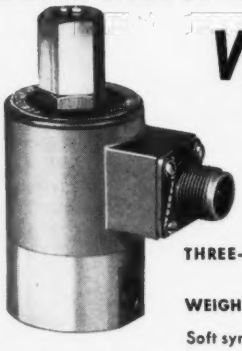

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The evening's principal speaker was Dr. Harold M. Hipsh, of Bendix Aviation Corporation. He spoke to the group about two comparatively new fields in aeronautical engineering, preliminary design and systems analysis. Until recently, Dr. Hipsh pointed out, the military services held the initiative in preliminary design and set up specifications for aircraft to meet their own needs.

Because of increased complexity of aircraft and guided missiles, this procedure has become inadequate, and the industry has called upon the systems analyst to determine aircraft requirements.

The preliminary design engineer, who writes the initial specifications, must be a man of broad knowledge and experience in an industry of specialists.

Only by considering simultaneously the various branches of aeronautical engineering—"thinking in total"—can the problems of preliminary design be solved successfully, said Dr. Hipsh, and upon their solution depends future progress in the face of increasing complexity.

University of Washington

Weston M. Howard, *Secretary*

At the December 8 meeting, Robert Ward, Advertising and Promotion Manager of Central Aircraft in Spokane, Wash., gave an interesting and enlightening talk on the problems of crop dusting. Typical problems were explained so that their relation to airplane design could be analyzed. Chairman William Rae presided; 28 students were present.

University of Wyoming

William C. Grove, *Secretary*

The new University of Wyoming Student Branch held its second meeting on December 18 with Chairman Alan Vinzant presiding. The attendance was 18 persons, including a guest, Prof. Eric J. Lindahl, Head of the Mechanical Engineering Department.

Two members, A. Ornelas and C. Buckert, were elected to represent the group in the Engineering Council of the university.

The excellent Northrop Aircraft sound and color film, *The Flying Wing Bomber*, was shown and thoroughly enjoyed by all.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Transferred to Associate Fellow Grade

Krivetsky, Alexander, M.S. in Ae.E., Acting Section Head, Methods & Allowables, Struct. Dept., Bell Aircraft Corp.

Peterson, Hillis S., B.S. in M.E., Sr. Proj. Engr., East Coast Aeronautics, Inc.

Volluz, R. J., B.S.M.E., Head, Supersonic Wind Tunnel, Consolidated Vultee Aircraft Corp. (Daingerfield).

Wetzel, Albert J., M.S. in Engrg. (Aero.), Lt. Col., USAF; Asst. to the Dir. of Guided Missiles, Office of the Secretary of Defense, Dept. of Defense (Washington, D.C.).

Elected to MEMBER Grade

Ackley, Richard H., M.S. in M.E., Technical Engr., Aircraft Gas Turbine Div., Air Design Sect., General Electric Co. (Lynn).

Apoian, Harry, M.M.E., Instr., Mech. Engrg. Dept., Villanova College.

Bagby, Frederick L., Jr., B.S. in Mech. & Aero. Engrg., Asst. Supvr., Battelle Memorial Institute.

Barnett, Roger M., B.S. in M.E., Research Engr., Jet Propulsion Lab., California Institute of Technology.

Collamore, Frank N., B.S.E.E., Proj. Engr., Jack & Heintz, Inc.

Douglass, William E., B.S. in M.E., Application Engr., Westinghouse Electric Corp.

Escher, Peter H., M.E., Aerophysics Engr., Aerophysics Devel. Corp.

Flanagan, Lindley E., Jr., B.S.Ae.E., Research Engr. "A," Aerophysics Lab., North American Aviation, Inc.

Gafarian, A. V., B.S. in M.E., Aerodynamicist, Aerophysics Devel. Corp.

Gates, Chester R., M.S. in Ae.E., Aero. Power Plant Research Engr., A.F.D.A.P., Office of Asst. for Devel. Planning, U.S.A.F.

Helmbold, Heinrich B., Proj. Engr., Univ. of Wichita.

Jacobs, John F., Jr., B.Sc., Dir. of Electro-Mech. Engrg., The W. L. Maxson Corp.

Long, Roger A., B.S.C.M.E., Gen. Mgr., Aeromet Div., Ferro Therm Co. (Cleveland).

Merer, George E., B.A., Supervisory Electronic Engr., Watson Lab. (Red Bank, N.J.); Rome Air Devel. Center, Griffiss Air Force Base (Rome, N.Y.).

Olden, Herbert, B.A.E., Asst. Editor, *Aviation Age*, Conover-Mast Publications.

Pappas, Constantine A., B.S. in M.E., Capt., U.S.A.F.; Research & Devel. Staff Officer; Chief, Bomber Defense & Bomber Fire Control Br., Fire Control Div., Hq., A.R.D.C. (Baltimore).

Roberts, Melvin L., B. of M.E., Associate Design Engr., The Edo Corp.

Rogers, Nelson M., B.S., R. & D. Staff Asst., W.A.D.C., U.S.A.F., Wright-Patterson A.F.B.

Schnittger, Jan R., Tekn. Lic., Asst. Prof. of Aero. Engrg., Massachusetts Institute of Technology.

Slaughter, Jack D., Proj. Engr., Aircraft Div., Surface Combustion Corp.

Whitaker, Robert C., B.S. in Ae.E., Devel. Engr., Marquardt Aircraft Co.

Wilmerding, John V., B. of A.E., Sr. Flight Test Engr., Republic Aviation Corp.

Transferred to MEMBER Grade

Bower, Robert E., M.A.E., Research Engr., Supersonic Aerodynamics, Grumman Aircraft Engineering Corp.

Gebhard, David F., M.Sc., Research Asst., Forrestal Research Center, Princeton Univ.

Grogan, George C., Jr., M.S. in Ae.E., Sr. Aerodynamics Engr., Consolidated Vultee Aircraft Corp. (Ft. Worth).

Johnson, Aldie E., Jr., B.S. in Ae.E., Aero. Research Scientist, Struct. Div., N.A.C.A., Langley A.F.B.

Kaplan, David H., B. Aero. E.

Mock, Bernard L., B.S. in Ae.E., Sr. Engr.—Aero., Group Leader, Marquardt Aircraft Co.

Ross, Arthur Leonard, M.Ae.E., Research Asst., Aero. Dept., New York Univ.

Sweeney, Marvin W., Jr., S.B., Research Asst., Aero. Engrg. Dept., Massachusetts Institute of Technology.

Elected to Technical Member Grade

Boyer, Keith D., Lt. (j.g.) and Naval Aviator, U.S.N.

Brantley, James Q., Jr., Dr. of Philosophy, Associate Research Engr., Cornell Aero. Lab., Inc.

Cartmel, Jacob A. B., Helicopter Aerodynamicist, Percival Aircraft, Ltd.

Gause, Charles I., Jr., B.S. in Education, Liaison Engr., Grand Central Aircraft Co.

Green, Harold H., Jr., B.S.E.E., Technical Engr., Aviation Gas Turbine Div., General Electric Co. (West Lynn).

Hyde, David, B.A., Industrial Engr., Boeing Airplane Co. (Renton).

McLean, Ronald E., Engrg. Draftsman, Grand Central Aircraft Co.

Nelson, Sidney, M.E., Material Review Engr., Republic Aviation Corp.

Transferred to Technical Member Grade

Adams, Donald N., Aerodynamicist, Fletcher Aviation Corp.

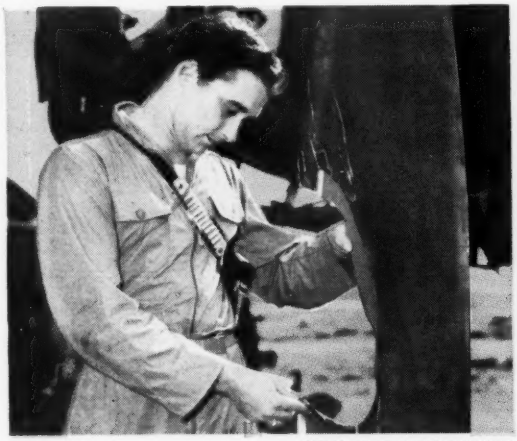
Adornato, Joseph V., Struct. Test Engr., North American Aviation, Inc. (Ohio).

Buice, William R., B.S., Lt., U.S.A.F.; Proj. Officer, Fire Control Br., Air Force Armament Center, Elgin A.F.B.

Cobb, James O., M.S. in Ae.E., Col., U.S.A.F.; Chief, Wind Tunnel Br., Aircraft Lab., A.D.C., Wright-Patterson A.F.B.

Aeroproducts reports...

AEROPROPS KEEP GOING DESPITE SEVERE FLAK DAMAGE



OFFICIAL U. S. NAVY PHOTO

Lieutenant (jg) Robert C. Notz, USN, inspects the Aeroprop blade that brought him safely back from a North Korean target. Flying from fast carrier Task Force 77, Lt. Notz' AD fighter-bomber was hit by Red flak during a low level attack. A bite approximately 18 inches long was taken out of the trailing edge of the blade deep into the rib section. The blade remained intact and enabled him to reach a repair base. A new Aeroprop blade was installed without removing the propeller and the ship was returned immediately to combat.

OFFICIAL U. S. NAVY PHOTO

Now Lieutenant Commander Lynn DuTemple knows why his AD *Skymaster* raised such a howl when he brought it aboard the USS *Princeton* off Korea. A 37mm enemy anti-aircraft shell had torn a gaping hole completely through one blade of his Aeroprop. LCdr DuTemple had just completed his fourth bombing run on Hamhung railroad bridge when the flak ripped through his prop blade and shattered his canopy. The pierced Aeroprop blade did not alter its performance enough to reveal the damage until the plane had reached its carrier base.

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DeLacio, George M., B.S. in Ae.E., Test Engr., Stratos Div., Fairchild Engine & Airplane Corp.

Dike, Donald J., B.S. in Ae.E., Jr. Aerodynamics Engr., Consolidated Vultee Aircraft Corp. (San Diego).

Graziani, Gerald, B.S.E. (Aero. & Math.), Engr., Guided Missiles Div., Douglas Aircraft Co., Inc. (Santa Monica).

Hama, Francis R., Ph.D., Research Associate & Instructor, Iowa Institute of Hydraulic Research, State University of Iowa.

Johnson, Charles G., B.Ch.E., Capt., U.S.A.F.; Proj. Officer, Armament Center, Eglin A.F.B.

Lembeck, Edward A., II, B.S., Capt., U.S.A.F.; Proj. Officer, A.F.A.C., Eglin A.F.B.

Liljeblad, Harry G., B.S. in Ae.E., Proj. Engr., Aircraft Engine Div., Ford Motor Co.

Lotrick, Joseph, Field Technical Rep., North American Aviation, Inc. (Los Angeles).

Marsh, Keith R., B.S. in Ae.E., Aerodynamicist, Temco Aircraft Corp.

Nielson, James C., B.S. in Ae.E., Jr. Engr. "A"—Experimental, Boeing Airplane Co. (Seattle).

Prouty, Raymond W., B.S. in Ae.E., Aero. Engr., Aerodynamics Sect., Helicopter Research Group, Hughes Aircraft Co.

Roensch, Robert L., B.S. in Ae.E., Student & Research Asst., Univ. of Michigan.

Schelp, Donald A., B.S. in Ae.E., Jr. Engr., Aerodynamics Dept., Boeing Airplane Co.

Schuler, John M., B.S.E. in Ae.E., Aerodynamicist "B," Stability & Control Group, Douglas Aircraft Co., Inc. (El Segundo).

Shafer, Harold R., Design Draftsman, Steel Products Engineering Co.

Startzell, Dale E., B.S., Design Engr., Engineering & Research Corp.

Stennes, Arthur J., B.S.M.E. (Aero.), Process Engr., Federal Cartridge Co.

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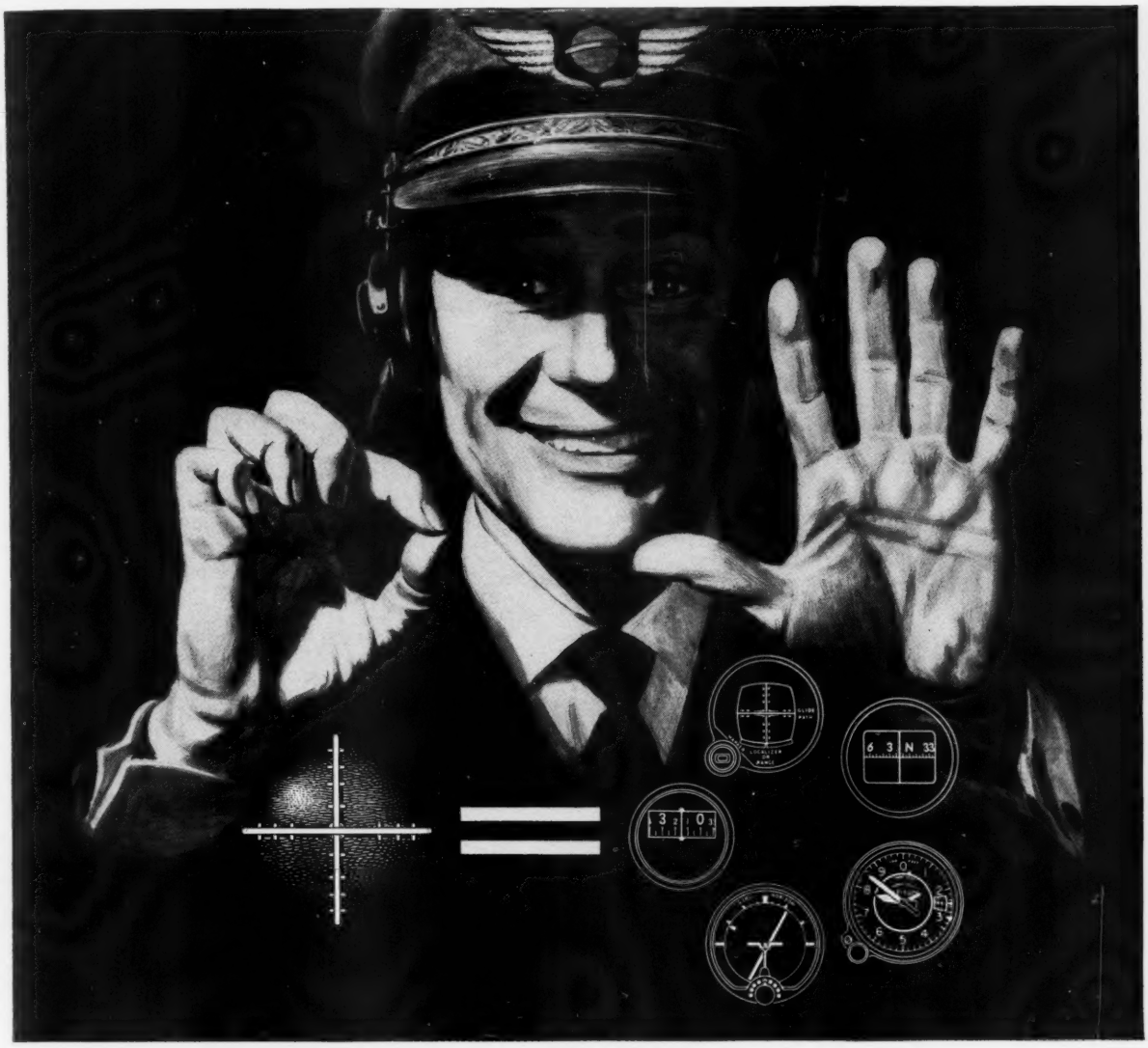

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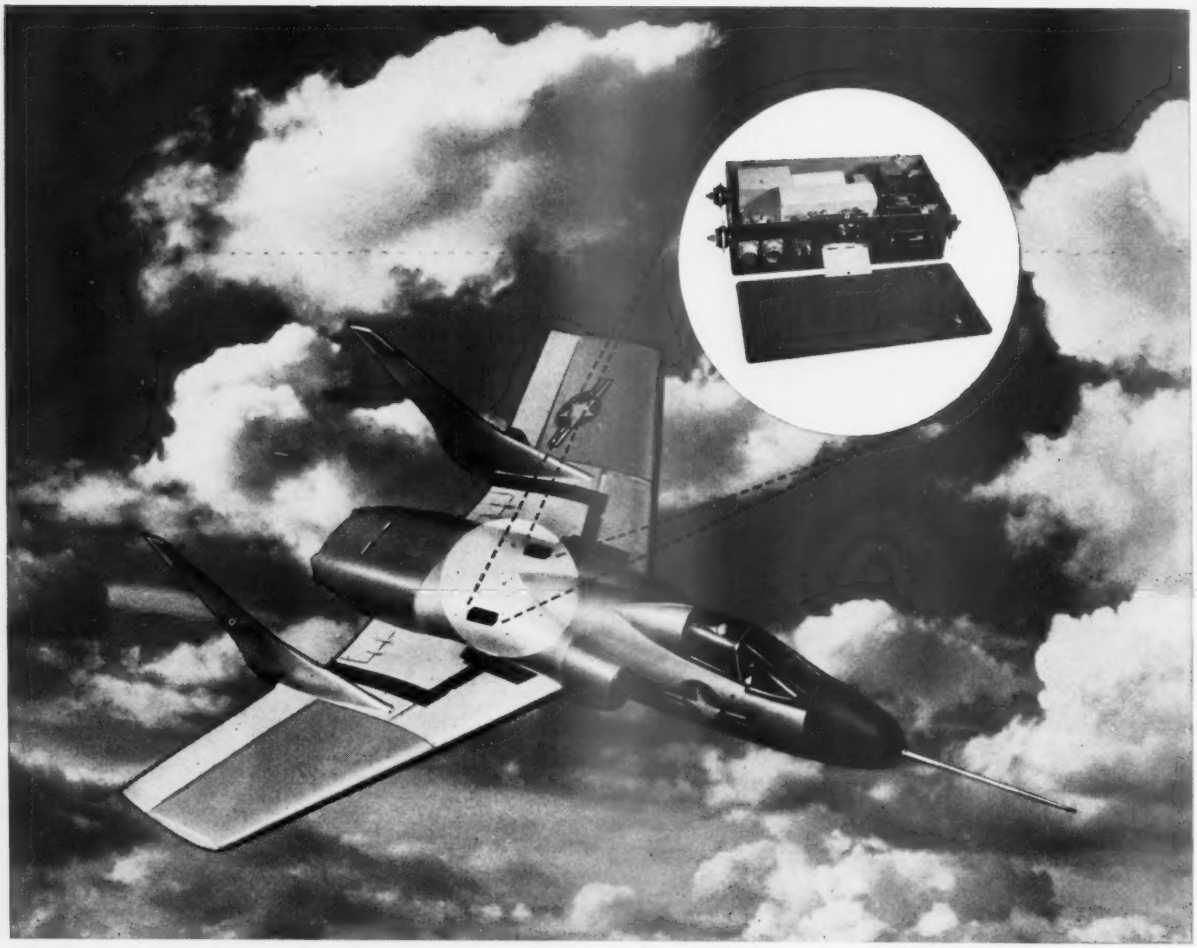

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Aerodynamics

On the Motion of a Tumbling Body. A. M. O. Smith. *Journal of the Aeronautical Sciences*, Vol. 20, No. 2, February, 1953, pp. 73–84, illus. 10 references. Investigation of jettisonable nose motions on the Douglas D-558 and D-558-2 high-speed research aircraft.

Readers' Forum: Relation of Force, Acceleration, and Momentum for a Body Whose Mass is Varying. H. W. Sibert. *Journal of the Aeronautical Sciences*, Vol. 20, No. 2, February, 1953, pp. 141, 142, illus. 1 reference.

Boundary Layer & Thermoaerodynamics

Readers' Forum: On the Boundary-Layer Equations in Hypersonic Flow and Their Approximate Solutions. Lester Lees. *Journal of the Aeronautical Sciences*, Vol. 20, No. 2, February, 1953, pp. 143–145, illus. 8 references.

Readers' Forum: On Asymptotic Solutions for the Heat Transfer at Varying Wall Temperatures in a Laminar Boundary Layer with Hartree's Velocity Profiles. H. Schuh. *Journal of the Aeronautical Sciences*, Vol. 20, No. 2, February, 1953, pp. 146, 147, illus. 9 references.

Readers' Forum: Some Remarks on "A Solution of the Laminar Boundary-Layer Equations for a Compressible Fluid with Variable Properties, Including Dissociation" by L. L. Moore. M. Z. Krzywoblocki. *Journal of the Aeronautical Sciences*, Vol. 20, No. 2, February, 1953, p. 136. 1 reference.

Readers' Forum: Energy Removal from a Supersonic Turbulent Boundary Layer. John Joseph Martin. *Journal of the Aeronautical Sciences*, Vol. 20, No. 2, February, 1953, pp. 140, 141, illus. 2 references.

Readers' Forum: Graphical Solution for "Turbulent Boundary Layer in Compressible Fluids" by E. R. Van Driest. John Joseph Martin. *Journal of the Aeronautical Sciences*, Vol. 20, No. 2, February, 1953, pp. 147, 148, illus. 1 reference.

Readers' Forum: Further Comments on "Turbulent Boundary-Layer Characteristics at Supersonic Speeds . . ." by R. E. Wilson. R. J. Monaghan. *Journal of the Aeronautical Sciences*, Vol. 20, No. 2, February, 1953, p. 142, illus. 5 references.

Control Surfaces

Low-Speed Wind-Tunnel Tests of Fowler Flaps, Slats and Nose Flaps on a Model of a Jet Aircraft with a 40 deg Swept-Back Wing. A. Spence. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2752*, 1952 (November, 1948). 18 pp., illus. 1 reference. British Information Services, New York. $1.25.

Theoretical Investigations of Ternary Lifting Surface—Control Surface—Trimming Tab Flutter and Derivation of a Flutter Criterion. H. Wittmeyer. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2671*, 1952 (October, 1948). 42 pp., illus. 13 references. British Information Services, New York. $2.50.

Equations and Charts for the Rapid Estimation of Hinge-Moment and Effectiveness Parameters for Trailing-Edge Controls Having Leading and Trailing Edges Swept Ahead of the Mach Lines. Kennith L. Goin. (*U.S., N.A.C.A., Technical Note No. 2221*, 1950.) *U.S., N.A.C.A., Report No. 1041*, 1951. 71 pp., illus. 10 references. Superintendent of Documents, Washington, $0.50.

Fluid Mechanics & Aerodynamic Theory

The Dust Problem in Hot-Wire Anemometry. D. C. Collis. *Aeronautical Quarterly*, Vol. 4, Part I, August, 1952, pp. 93–102, illus. 7 references.

Hydraulic Resistance Effect Upon the Dam-Break Functions. Robert F. Dressler. *U.S., National Bureau of Standards, Journal of Research*, Vol. 49, No. 3, September, 1952, pp. 217–225, illus. 12 references. (Also available as *Research Paper No. 2356*. Superintendent of Documents, Washington. $0.10.)

Interaction Between a Supersonic Stream and a Parallel Subsonic Stream Bounded by Fluid at Rest. Herbert S. Ribner and E. Leonard Arnoff. *U.S., N.A.C.A., Technical Note No. 2860*, December, 1952. 45 pp., illus. 10 references.

On the Stability of the Laminar Mixing Region Between Two Parallel Streams in a Gas. C. C. Lin. *U.S., N.A.C.A., Technical Note No. 2887*, January, 1953. 50 pp., illus. 9 references.

Propagation of Elastic Waves in a Cylindrical Bore Containing a Fluid. M. A. Biot. *Journal of Applied Physics*, Vol. 23, No. 9, September, 1952, pp. 997–1005, illus. 1 reference.

Reverse-Flow and Variational Theorems for Lifting Surfaces in Nonstationary Compressible Flow. A. H. Flax. *Journal of the Aeronautical Sciences*, Vol. 20, No. 2, February, 1953, pp. 120–126, illus. 13 references.

The Sensitivity and Range Required in a Toepler Schlieren Apparatus for Photography of High-Speed Air Flow. W. A. Mair. **Note on Mr. Mair's Paper.** D. W. Holder and R. J. North. *Aeronautical Quarterly*, Vol. 4, Part I, August 1952, pp. 19–53, illus. 10 references.

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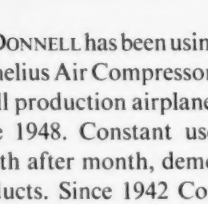

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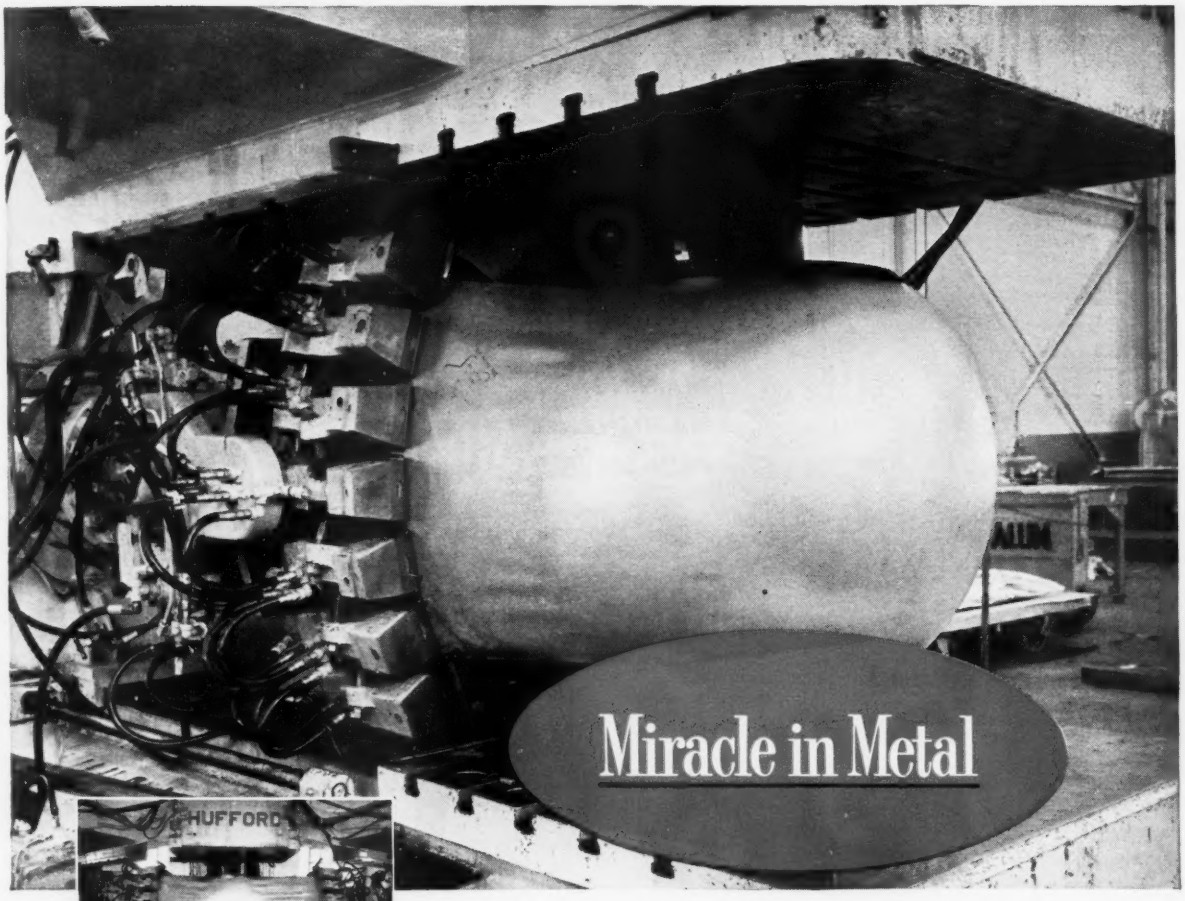

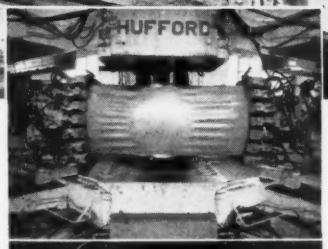

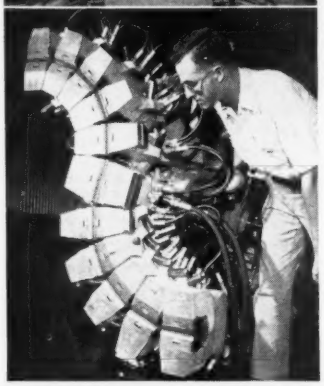

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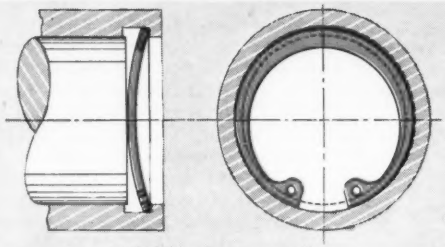

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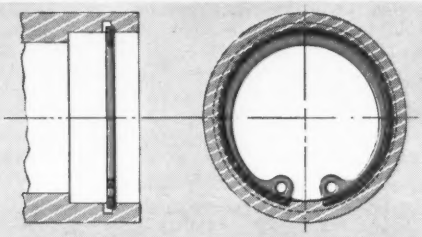

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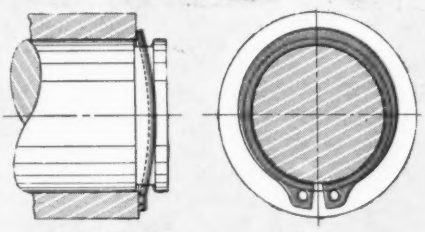

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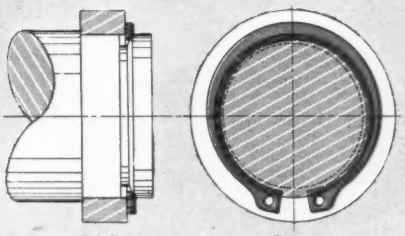

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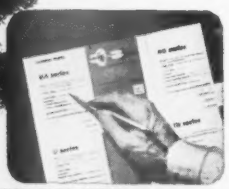

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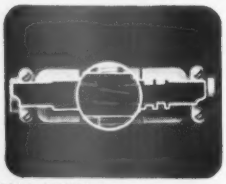

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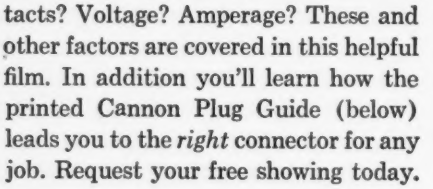

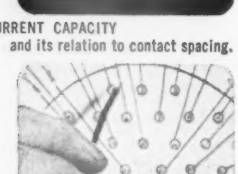

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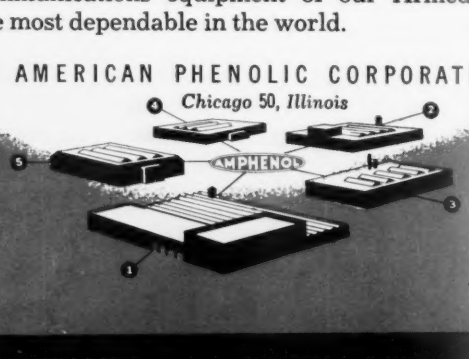

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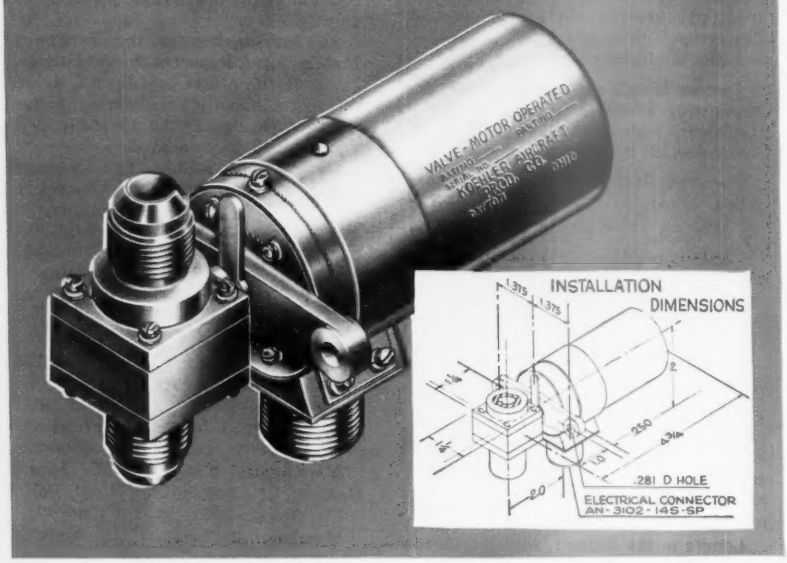

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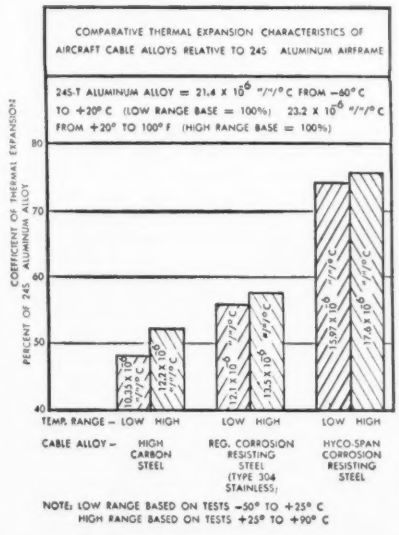
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70
60
50
40
10.3 X 10⁻⁶ "/"/°C
12.2 X 10⁻⁶ "/"/°C
12.1 X 10⁻⁶ "/"/°C
13.5 X 10⁻⁶ "/"/°C
15.9 X 10⁻⁶ "/"/°C
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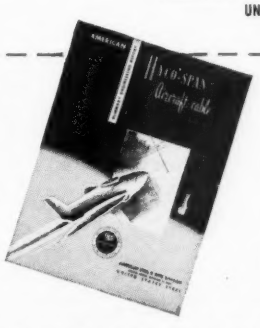

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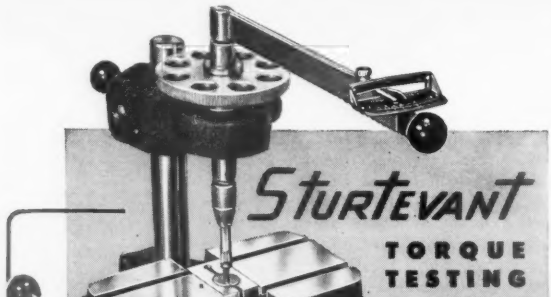

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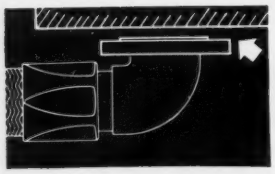

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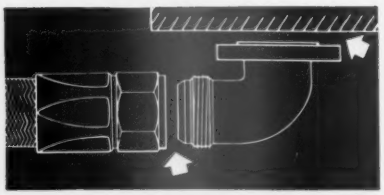

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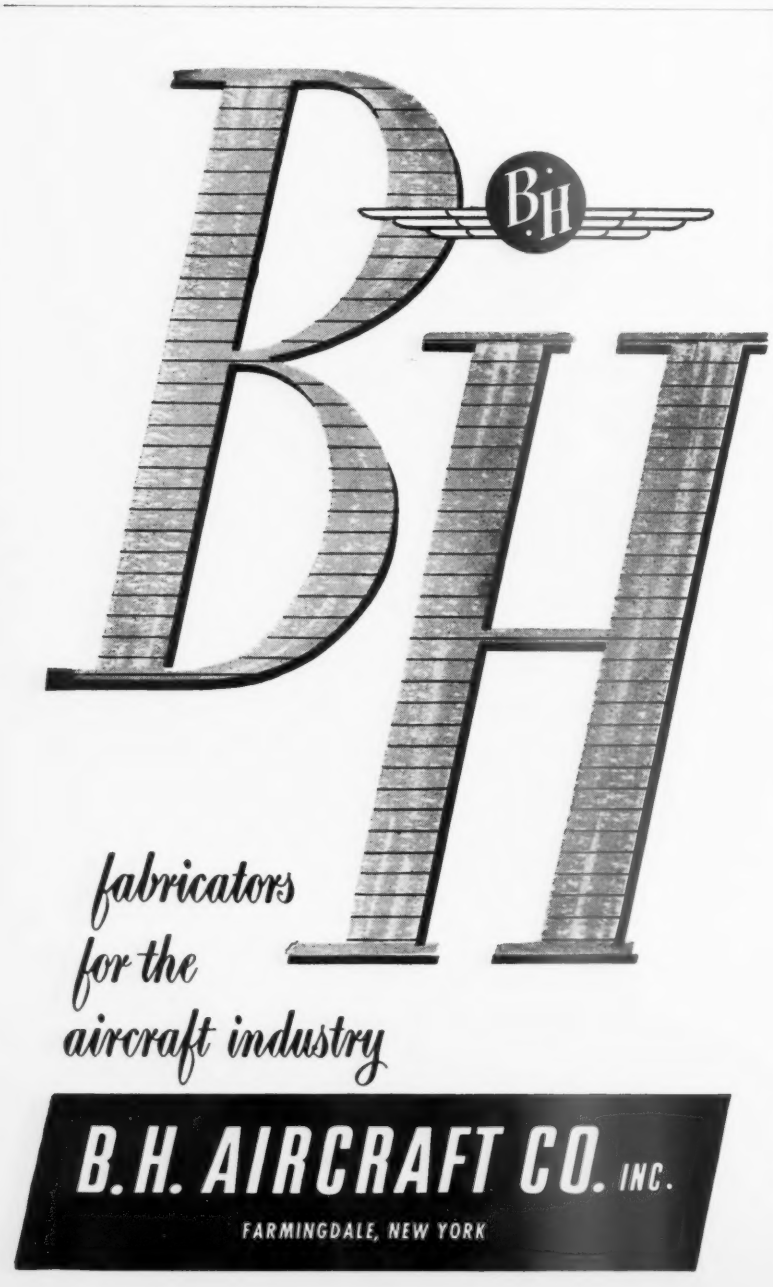

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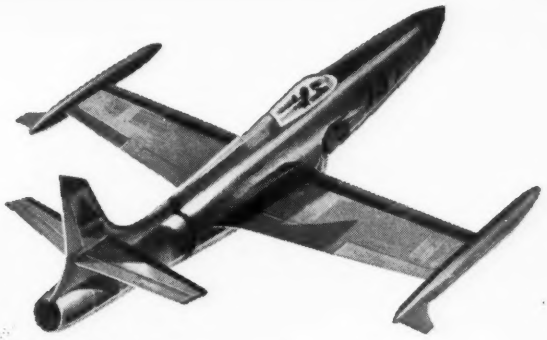

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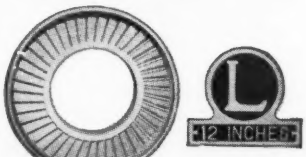

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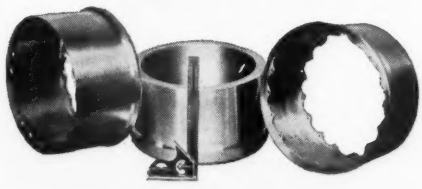

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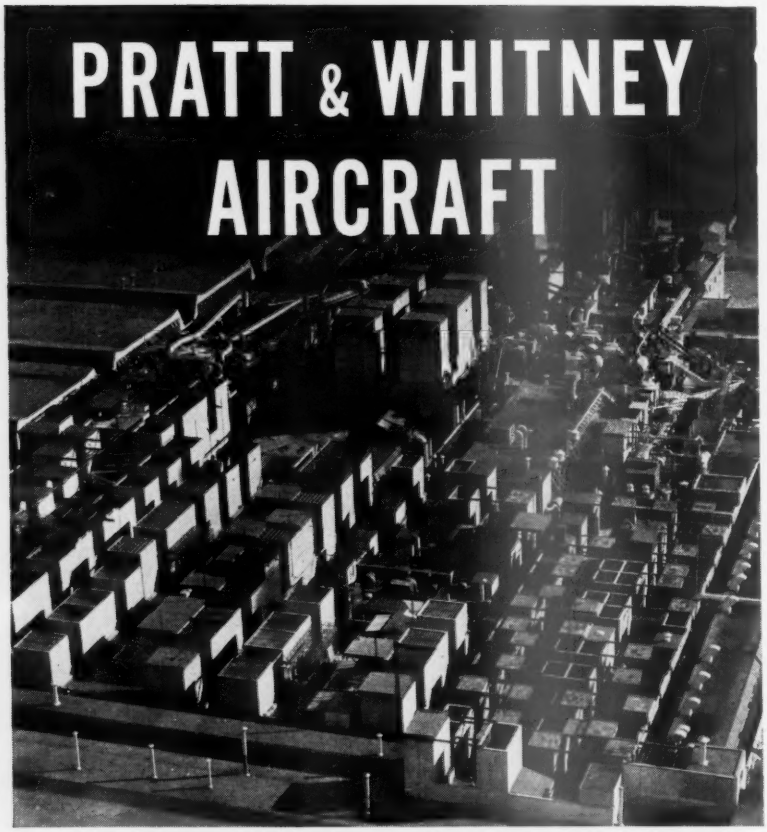

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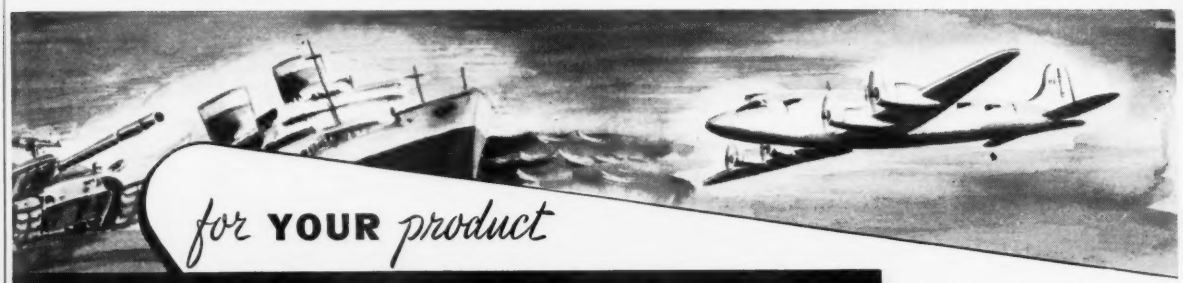

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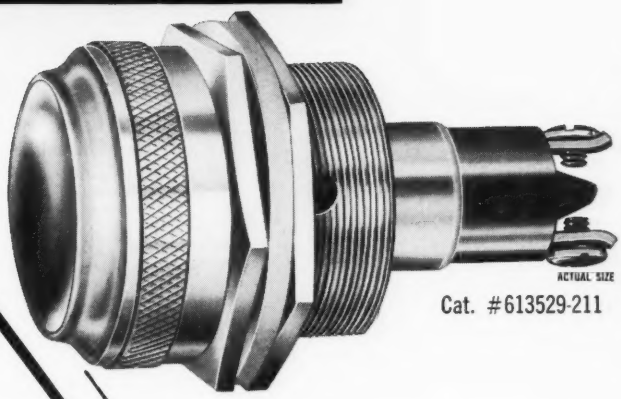

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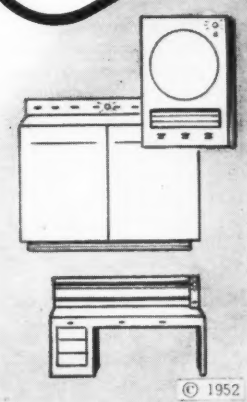

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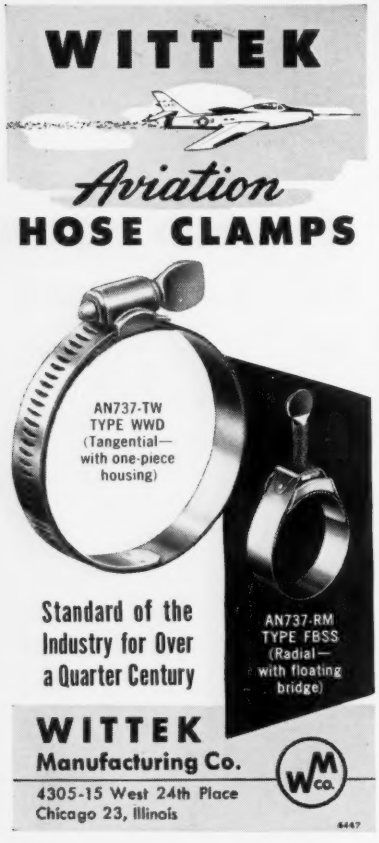

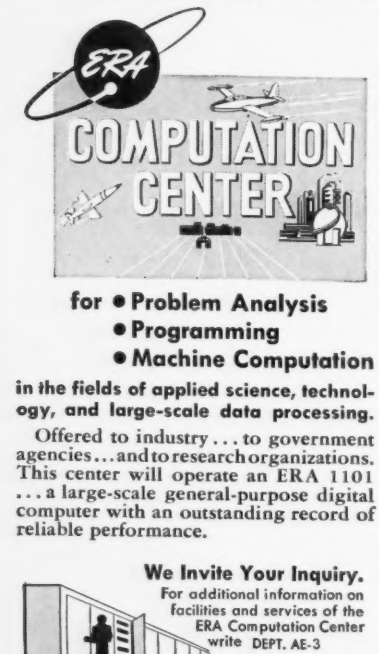
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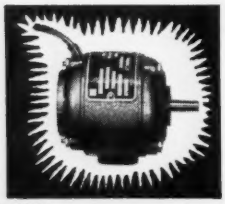
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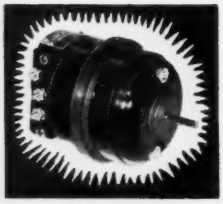
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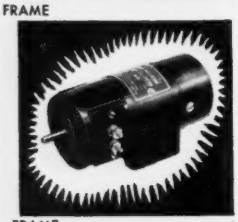
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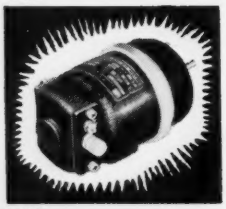
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(Edwards) Air Force Base Tests High-Speed Aircraft. J. S. Holtoner and F. J. Ascani. *SAE Journal*, Vol. 61, No. 1, January, 1953, pp. 56–61, illus.

Instruction and Research in Hydraulic Laboratories. Herbert Addison. *The Engineer*, Vol. 194, No. 5054, December 5, 1952, pp. 769–772, illus. 13 references. At the Fouad I University, Faculty of Engineering, Giza, Egypt.

Test Cell Protection at Westinghouse Jet Engine Plant. *Automotive Industries*, Vol. 107, No. 8, October 15, 1952, pp. 33, 114, illus. Fire monitoring system.

Torture for Tyres; The Dunlop Aircraft-tyre Test-house; Novel Ground-duty for a Merlin Engine. *Flight*, Vol. 62, No. 2291, December 19, 1952, pp. 751, 752, illus.

The United Steel Companies Ltd. New Research and Development Department; The Swindon Laboratories, Rotherham. *Metal Treatment*, Vol. 19, No. 83, August, 1952, pp. 343–346, 354, illus.

Wind Tunnels in the High Speed Aerodynamics Laboratory. J. Lukasiewicz. *Canada, National Aeronautical Establishment, Aeronautical Laboratories, Quarterly Bulletin*, October 1–December 31, 1952, pp. 1–8, illus.

Jet Test-bed Silencing. *The Aeroplane*, Vol. 83, No. 2160, December 12, 1952, p. 789, illus. The Cullom Detuner.

Stovepipe Laboratory. *Flight*, Vol. 62, No. 2281, October 10, 1952, p. 477, illus. Pratt and Whitney ram-jet test house.

Test-House Silencing; Methods Employed on the Olympus Test-beds at Bristol. *Flight*, Vol. 62, No. 2290, December 12, 1952, p. 734, illus.

Air Power and New Weapons

(*Concluded from page 82*)

plexity of modern air weapons, we are in danger of being stalled on the threshold of great achievements by some seeming trifle that research has overlooked. Related subjects like weather prediction and human limitations under stress take on an added importance. The success of an entire new weapons system may hang on the success of an innovation as minor as liquid suspension for gyroscopes.

There is one type of improvement necessary for nearly all the thousands of items we carry on our combat planes. I refer to weight reduction. We must continue to meet and defeat the sparely equipped, lighter, and more numerous aircraft of our enemies. But we are determined to do it without sacrificing the lives of our pilots in flimsy or incomplete planes and without abandoning our present superiority in auxiliary combat equipment. Here again we must call upon scientists and technicians to provide us with the answers.

The big question is—can the free world defeat the massive threat of Communism? This can be answered only as you provide us with solutions such as a few ounces of weight saved in each of a thousand component parts.

It is upon areas such as these that we should endeavor to concentrate interest rather than upon visions of weird mechanical monsters swarming across land, sea, and sky at some unknown date. Terrors already unleashed are sufficient to destroy us unless we act in hope instead of shivering in fear.

Let us continue to discuss all science's contributions to military strength, both present and future—but always with due regard for the realities of the moment. What we are doing and trying to do in the field of new weapons is too important to be exaggerated or distorted for purposes of vainglory.

Boasts and claims serve to obscure real achievements and to becloud the minds of everyone but our skeptical and realistic enemies. Upon the hard, tedious, and often anonymous work of the true scientist and engineer depends the survival of the free world.

We face an enemy who has outdone every tryanny of prior history in exploiting human masses as expendable weapons. Now he is challenging our superiority in the sciences and the technical skills.

All honor, then, to those who are being cited by the I.A.S. for their contributions to aeronautics, which—though individual—symbolize the fine work that all of you are doing in this field. The free world depends upon you to prove that, contrary to the cynical view, providence is not necessarily on the side of the big battalions.

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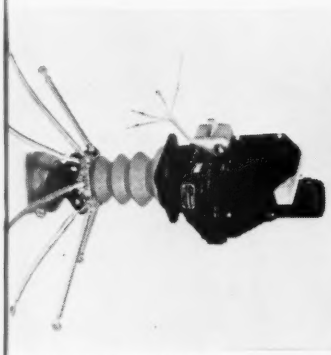

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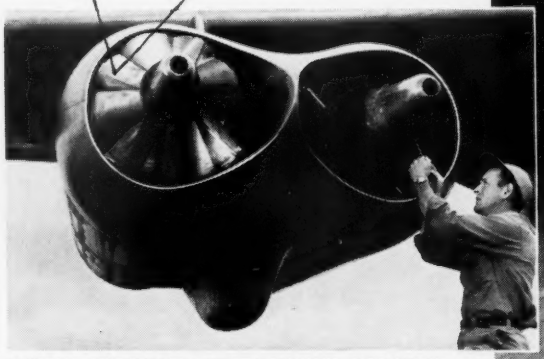

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Aeronautical Reviews — BOOKS

Elasticity in Engineering

By Ernest E. Sechler. New York, John Wiley & Sons, Inc., 1952. 416 pp., figs. $8.50.

According to the preface, this book has been written primarily for engineers working in all fields of structural analysis, trying to bring into one volume the material of most interest to the engineer who needs a broad foundation based on the fundamental theories of stress and deformation of elastic bodies under load.

Part I contains the stress-strain relations, including Airy's stress function, and elastic energy principles. Part II deals with redundant structures, two-dimensional problems, torsion, and the theory of plates. Part III treats instability, including a short section on instability of plates.

In his derivations, the author follows closely Timoshenko's well-known works on *Theory of Elasticity* and *Plates and Shells and Elastic Stability*, sometimes inserting intermediate steps. Hence, the present book could be a good introduction to these more complete works. In this connection, it is unfortunate that the author uses other, rather arbitrary axis notations.

More unfortunately, however, the author is rather inaccurate in his more explanatory statements. On page 3, instead of defining a fluid as a body that, at rest, cannot take any shear stresses, he defines it as a body that will deform under the action of infinitesimal forces, which, as he concedes, does not hold any longer for all sided pressure. Figs. 2.3 and 2.4 on pages 11 and 12 are wrong, since they assume uniform stresses in the case of cylindrical and spherical coordinates, which are impossible in these cases; his elements are not in equilibrium. On page 42, the rotation is defined as the change in slope of the diagonal of an element instead of that of the principal axes of strain. On pages 100, 101, 317, and 319, errors are made in the signs, leading to positive deflections by negative loads. On page 338, the author tries to explain that the second-order equation for buckling of columns leads to erroneous and incomplete solutions for a column with both ends fixed. However, the error occurs because equation (13.14), which is derived from the conditions of zero and slopes only, is considered as a solution, which it is not, since it does not satisfy the condition of zero end deflections. The incompleteness is due to the omission of the term $(Qy)/(EI)$ in the differential equation (13.10) where Q is the end shear, which must be included to provide for the unsymmetrical modes.

Here follow some minor objections. In Fig. 5.5 on page 67, the horizontal part of the stress-strain diagram of mild steel is about ten times too short. The definition of the change of potential energy on page 112 is misleading. For educational purposes it is unfortunate that on pages 175 and 240 the author draws moment diagrams with alternating curvature for simply supported beams with loading of constant sign, especially since American students tend to make such errors, probably because American textbooks do not stress the connection between moment diagram and funicular polygon. On page 185, the author says that the true deflection shape of a beam subjected to a constant bending moment is a parabola but that for small deflections a circular arc is a sufficiently close approximation.

He also states that anticlastic bending does not follow from the simple beam theory. On page 262, it is stated that X, Y, and Z are the components of the normal stress N rather than of the total stress. From the figures on pages 335 and 341, one would get a better idea of the buckling phenomenon by drawing the pressure line of the compressive force, showing that the column always buckles in sine waves with respect to the pressure line. Minor omissions occur in Figs. 4.1(a) and 8.11.

The book is excellently printed. The reviewer did not find a single misprint. When the above objections are eliminated, the book can be useful as a textbook for a general graduate course in elasticity, for which Timoshenko's books may be considered as too extensive.

P. P. Bijlaard
Professor of Structural Engineering
Cornell University

For information on I.A.S. Library Service Facilities, see page 108

Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

Author's Reply

I would first like to express my appreciation to Professor Bijlaard for his sincere and careful review of my new book *Elasticity in Engineering*. Really critical reviews such as this will materially aid in improving such texts for the use of students and practicing engineers. His comments will be discussed in the order of their presentation.

(1) I found it inadvisable to use the same axis notation used in the other texts mentioned, since, in those texts, axis notations differed from book to book and often from section to section in the same book. I therefore preferred to establish one axis notation and tried to keep it consistent throughout.

(2) The fluid mechanics people object to defining a fluid as one that cannot support shear stresses. The exact definition of a fluid would take more space than could be justified in this text.

(3) Figs. 2.3 and 2.4 should be more properly titled "Stress Notation in Cylindrical (Spherical) Coordinates," respectively. A uniform stress field is possible in both systems if certain terms shown in these figures are set equal to zero.

(4) Both definitions of rotation lead to the same results, and it was believed that the one used would be more easily visualized by the engineer.

(5) The signs as used on pages 100, 101, 317, and 319 are, I believe, correct as defined. On pages 100 and 101, P is taken as positive downward and deflections are taken as positive when in the direction of the applied load. On pages 317 and 319, positive P is as shown in Fig. 12.19 and positive deflections are in the direction of the applied load.

(6) The point of importance on page 338 is that no single second-order equation can yield all of the eigenvalues for the general column problem. Since there are always four natural boundary conditions, the definitive equation must be of fourth order.

(7) Concerning the minor objections, some of these are errors of omission which will be corrected; others are differences of opinion as to definitions which will always arise; others point to methods of presentation which may help avoid student errors, and I am thankful to Professor Bijlaard for bringing them to my attention.

E. E. SECHLER
Professor of Aeronautics
California Institute of Technology

Aerodynamic Drag; Practical Data on Aerodynamic Drag

Evaluated and Presented by Sighard F. Hoerner. Foreword by Walter S. Diehl. The author, 148 Busteed, Midland Park, N.J., 1951. 259 pp., diagrs., figs. $5.50.

S. F. Hoerner's book is a collection of practical data on aerodynamic drag and probably the most comprehensive reference book on this subject. Such books are extremely valuable and useful to everyone who does practical work in aerodynamics and related fields. The collection of drag data and formulas has been made so thoroughly that it is difficult to think of any item connected with drag which is missing from this book. Not only the aeronautical engineer will find answers to his problems but also people who are concerned with railroad vehicles, automobiles, ships, submarines, etc., will find detailed information in the book. The author also covers many questions on supersonic drag by reporting on a large variety of results from measurements in supersonic wind tunnels and in free flight and from theoretical derivations. Even the scanty results on drag in rarefied gases are included.

In some respects, it is unfortunate that the author did not find a publisher for the book, which would have eliminated several shortcomings in the formal presentation. This is particularly evident from the graphs, notation, and placing of references and footnotes. It is difficult to read the superfine script in the figures, and patience is required in reading and distinguishing between the numbers for formulas, figures, and references—e.g., (11,1), (11.1), Fig. 11.1.

This book will be found soon in all libraries where information on drag is desired by research personnel.

DR. H. H. KURZWEG
Chief, Aeroballistic Research Department
U.S. Naval Ordnance Laboratory
White Oak, Md.

Book Notes

AIRPLANE DESIGN

Climatic and Environmental Criteria for Aircraft Design; ANC-22 Bulletin. U.S. Munitions Board Aircraft Committee, Subcommittee on Air Force-Navy-Civil Aircraft Design Criteria. Washington, Superintendent of Documents, June, 1952. 65 pp., illus., figs. $0.35.

Contents: Introduction. Material Composition of the Atmosphere. Dynamic Forces in the Atmosphere. Solar Influences in the Atmosphere. Factors Dependent on Atmospheric Conditions for Existence.

Ground Loads; ANC-2 Bulletin. U.S., Munitions Board Aircraft Committee, Subcommittee on Air Force-Navy-Civil Aircraft Design Criteria. Washington, Superintendent of Documents, October, 1952. 20 pp., diagrs. $0.15.

Contents: Chapter 1, General. Chapter 2, Landing Conditions. Chapter 3, Taxiing Conditions. Chapter 4, Handling Conditions. Chapter 5, Miscellaneous Conditions. Chapter 6, Unconventional Gear Configurations and Helicopters. Chapter 7, Methods of Analysis.

MATERIALS

Symposium on Statistical Aspects of Fatigue. (Special Technical Publication No. 121), Philadelphia, American Society for Testing Materials, 1952. 64 pp., diagrs. $1.75.

Contents: Introduction, R. E. Peterson. Planning and Interpretation of Fatigue Tests, Alfred M. Freudenthal. On the Statistical Nature of Fatigue, Foster B. Stulen. Statistical Analysis of Fatigue Data, Robert Plunkett. Discussion.

Structure of Metals; Crystallographic Methods, Principles, and Data. Charles S. Barrett. 2nd Ed. New York, McGraw-Hill Book Company, Inc., 1952. 661 pp., illus., diagrs. $10.

The general plan of the first edition (1943) of this text and reference book has been retained throughout this revision. Much significant research has been published in the interval between editions, and the discussions and treatments of the previous edition have been expanded accordingly. Extensive revision has been made of the sections concerning dislocations, imperfections, creep, strures of solid and liquid metals and alloys, textures, and transformations. As before, many references have been given not only to original articles but also to detailed summaries of research data, symposiums, advanced textbooks, and other references that should prove helpful in bridging the gap between this book and a literature that has become extensive. As in the earlier edition, the last half of the book is devoted to the results of research and contains extensive reviews of fields that are of current interest.

POWER PLANTS

Raketenantriebe; Ihre Entwicklung, Anwendung und Zukunft (Rocket Motors; Their Development, Application, and Future). Josef Stemmer. Zurich, Schweizer Druck- und Verlagashaus AG., 1952. 534 pp., illus., diagrs., figs. Sw. Fr. 19.75.

The present work affords a general introduction to the complex problems of rocket motors, as well as rocket flight and space travel. Following a brief historical summary of rocket development and a chronology of important events and discoveries, fuels for pure rockets are discussed. Rockets with powder propellants, the problems of high-speed and high-altitude flight, and rockets using liquid propellants are treated in the next three chapters. Chapter 6 is concerned with performance and characteristics. Chapter 7, on the status of liquid-fuel rocket motors, contains contributions by Eugen Sänger and Heinz Gartmann. Chapter 8, which comprises one quarter of the book, analyzes the design and performance of rockets that have been built and flown. The final chapter examines the different aspects of the question of space travel. The book concludes with a 9-page list of selected references and an appendix containing a chart of the upper atmosphere and constructional diagrams.

Power Plants for Aircraft. Joseph Liston. New York, McGraw-Hill Book Company, Inc., 1953. 577 pp., illus., diagrs., figs. $8.50.

The primary objective of the author has been to provide a text and reference book for seniors and beginning graduate students in aeronautical and mechanical engineering. The emphasis is on fundamental principles, and a broad approach, involving the consideration of all types of aircraft power plants, is used. Further amplification of selected subjects can be made by utilizing the references cited. Review questions and problems are provided to aid the student in fixing the subject matter more fully in his mind. Review chapters on thermodynamics and fluid mechanics are not included because it was felt that the student could review more effectively by referring to the textbooks used for these courses. Illustrations are made an integral part of the work so that, in many cases, only a preliminary explanation is presented in the text, leaving the remainder summarized in the accompanying figure. Included in the presentation are comparisons of jet and reciprocating power plants, an analysis of the theoretical power-plant cycles, a comparison of actual engine performance with the theoretical cycles, and a discussion of practical problems encountered in operation and testing. The author is Professor of Aeronautical Engineering, Purdue University.

Contents: (1) Basic Requirements and Achievements. (2) Utilization of Available Energy. (3) Fuels. (4) Charge Handling. (5) Cylinder and Burner Phenomena. (6) Performance. (7) Turbine Engine Characteristics. (8) Structural and Mechanical Requirements.

PRODUCTION

The Welding of Non-Ferrous Metals. E. G. West. New York, John Wiley & Sons, Inc., 1951. 553 pp., illus., diagrs., figs. $8.50.

The purpose of this book is to place on record basic information on the application of the various welding processes to the nonferrous metals. It has been written with two main classes of reader in view: the welding engineer, welding operator, and welding instructor and trainee on the one hand and the designer, production engineer, and metallurgist on the other. Brief descriptions of the equipment and processes have been included, and brief explanations have been introduced whenever necessary to explain the metallurgical, physical, or chemical phenomena encountered in welding. Subject references to 353 original papers have been included throughout the book, and these have been gathered together toward the close of the book. The many tables and diagrams and the detailed index of subjects make the book useful for reference. The author is Technical Director of The Aluminium Development Association.

Contents: (1) Weldability. (2) Properties Important in Welding. (3) Summary of Fusion Welding Processes. (4) Resistance Welding Processes. (5) Pressure Welding. (6) The Welding of Aluminium and Its Alloys. (7) The Welding of Magnesium Alloys. (8) The Welding of Copper Alloys. (9) The Welding of Nickel and Its Alloys. (10) The Welding of Lead and Its Alloys. (11) The Welding of Zinc and Its Alloys. (12) The Welding of Low Melting Point Metals. (13) The Welding of High Melting Point Metals. (14) The Welding of Precious Metals.

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SCIENCES, GENERAL

CHEMISTRY

Diffusion in Solids, Liquids, Gases. W. Jost. New York, Academic Press, Inc., 1952. 558 pp., figs. $12.

Diffusion processes are dealt with on a broad basis, and the subject of chemical reactions in solids is entirely neglected except for such cases that could be described in terms of diffusion processes. Although the present monograph contains several theoretical chapters, it is the work of an experimental physical chemist. Its chief aim is to assist in planning, evaluating, and understanding diffusion experiments, at the same time giving a survey of the results obtained to date. The author is Professor of Physical Chemistry, Technische Hochschule, Darmstadt.

Contents: I, The Fundamental Laws of Diffusion. II, Disorder in Crystals. III, Theory of Diffusion in Solids. IV, Electrolytic Conduction and Diffusion in Ionic Crystals. V, Diffusion in Metals and in Non-Polar Crystals. VI, Solubility in Solids. VII, Permeation and Diffusion of Gases in Solids. VIII, Mobility of Ions in Solid and Molten Metals and Alloys. IX, Surface Reactions of Metals, Formation of Protective Layers and Related Reactions. X, Diffusion in Gases. XI, Diffusion in Liquids. XII, Thermal Diffusion. Author, Subject, and Formula Indexes.

MATHEMATICS

Linear Algebra and Projective Geometry. Reinhold Baer. New York, Academic Press Inc., 1952. 318 pp., figs. $6.50.

In this book it is intended to establish the essential structural identity of projective geometry and linear algebra. Theorems showing that certain geometrical concepts may be represented in algebraic fashion form the core of the discussion. These theorems are concerned with the representation of projective geometries by linear manifolds, of projectivities by semilinear transformations, of collineations by linear transformations, and of dualities by semibilinear forms. Dimensional restrictions are imposed only where necessary for the validity of the theorem under consideration. Some sections have been labeled "Appendix" since the topics treated in them are not needed for the main body of the discussion. The references given are designed almost exclusively to supply supplementary reading. Reinhold Baer is at the University of Illinois.

Linear Scale Non-Logarithmic Slide Rules. Morris Lewis Groder. Brooklyn 29, N.Y., G & G Corporation, 2003 East 12th Street, 1952. 64 pp., diagrs. $2.98.

This book is intended as a practical guide to the construction and operation of general- and special-purpose slide rules in which all scale divisions are equally spaced. Use of these devices for division, multiplication, combined operations, reciprocals, natural trigonometric functions, polar-rectangular coordinate conversion, squares and square roots, and common logarithms is described step by step. Other chapters are devoted to general principles, automatic index shifting, expansion of the linear scale, folded scales, special slide rules, multiplication and division with an ordinary ruler, and an electric linear-scale slide rule. Appendixes contain information on significant figures, powers of ten, decimal placement, squares and square-root techniques, and determination of the characteristic of a logarithm. The tools needed to construct these slide rules are a straight edge, pencil, cross section paper, and compass.

STRUCTURES

Proceedings of the Society for Experimental Stress Analysis; Vol. 10, No. 1. Cambridge, Mass., The Society, 1952. 245 pp., illus., diagrs., figs.

Contents: A Photoelastic Investigation of Quenching Stresses in Glass, K. A. Parsons. The Plate Analogy as a Means of Stress Analysis, J. J. Ryan. Improved Photogrid Techniques for Determination of Strain over Short Gage Lengths, J. A. Miller. Some Phases of the Technique of Recording Performance Data on Large Machines, J. H. Meier. Stress Concentrations Produced by Multiple Semi-Circular Notches in Infinite Plates under Uniaxial State of Stress, A. J. Durelli, R. L. Lake and E. Phillips. Mobile Instrumentation for Automotive Equipment, A. W. Colwell. Measurement of Force-Time Relations in Racing Shells, E. D. Baird and W. W. Soroka. The TMB Strain Cycle and Counter—An Instrument for the Statistical Determination of the Strain History of Structures, N. H. Jasper. Residual Stresses in Surface-Hardened Oil Field Pump Rods, R. E. Hanslip. Determination of Dynamic Stress-Strain Curves from Strain Waves in Long Bars, W. R. Campbell. Telemetering, Recording, and Analyzing Shock and Vibration Data, C. B. Cunningham. A Mechanical Deflection Gage—An Instrument for Measuring Displacement Under Impact, D. D. MacLaren, I. J. Taylor and L. S. Beedle. Measurement of the Resistance of Materials to Mechanical Shock, T. E. Pardue and B. Goldberg. Impulsive Loads on Beams, W. H. Hoppmann, II. Properties of Bolts under Shock Loading, H. M. Forkois, R. W. Conrad and I. Vigness. Elastic and Creep Properties of Stresscoat, W. F. Stokey. The Measurement of Turbine Stresses in Aircraft Engines in the Laboratory, on the Test Bed and in Flight, D. A. Drew. A Mechanism for Controlling Large-Scale Fatigue Testing Machines, W. J. Hall and G. K. Sinnamon. Longitudinal Impact of Cylindrical Bars, E. A. Ripperger. Stress Analysis of a Pipe Wrench, G. H. Eisenhardt and W. L. Walsh. Discussion of Paper entitled: Factors of Stress Concentration for the Bending Case of Fillets in Flat Bars and Shafts with Central Enlarged Section, A. J. Durelli and R. H. Jacobson. Discussion of Paper entitled: Quantitative Evaluation of Residual Stresses by the Stresscoat Drilling Technique, A. J. Durelli and C. H. Tsao. Letter to Editor: A Method of Waterproofing Electrical Strain Gages, H. O. Meyer.

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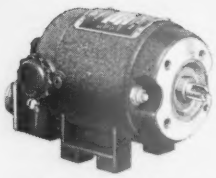

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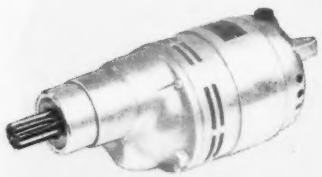

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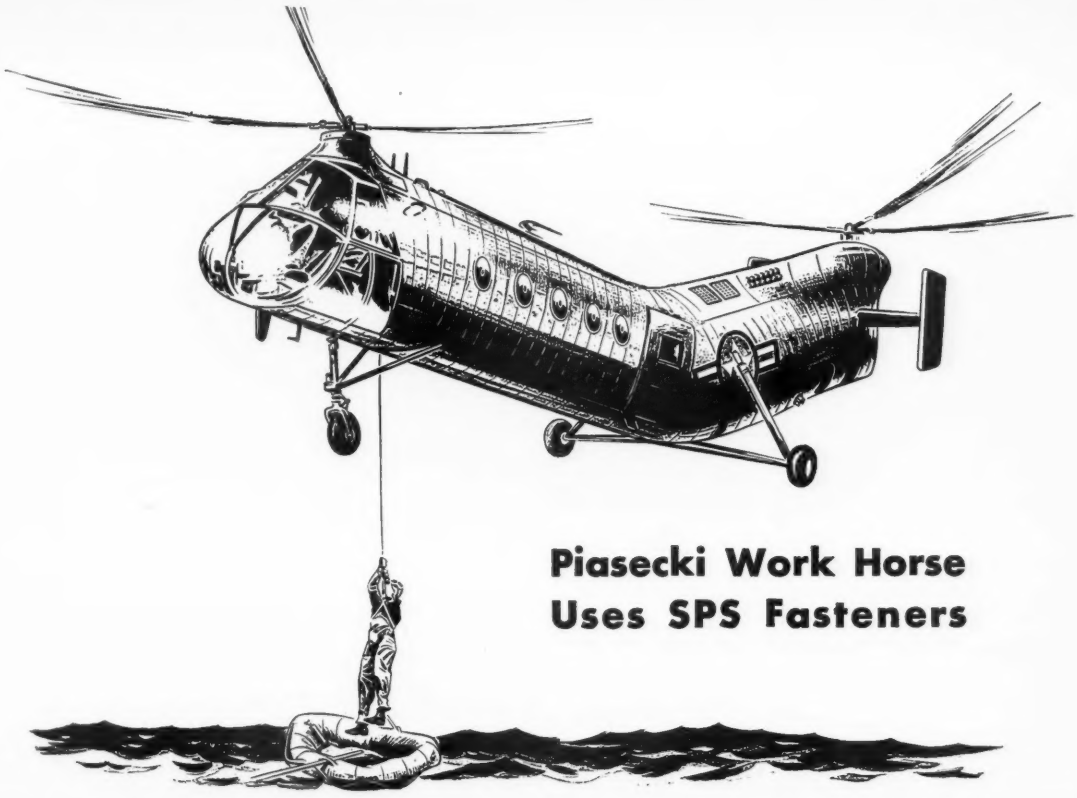

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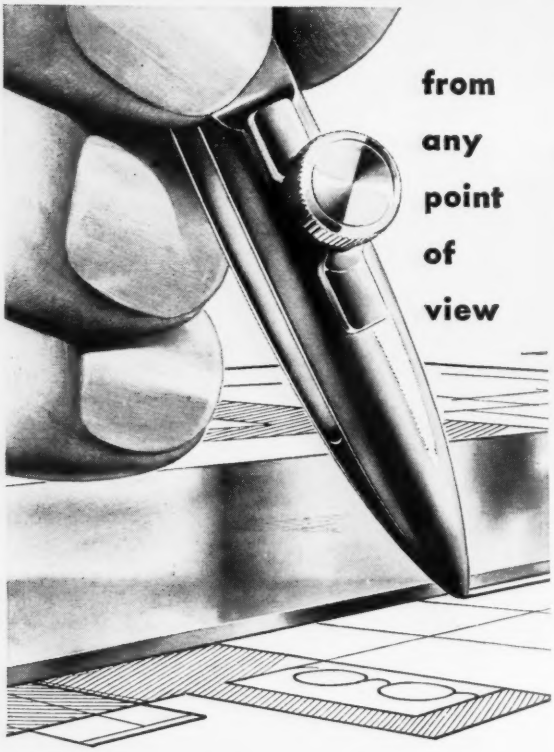

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